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JOURNAL

OF THE

Elisha Mitchell Scientific Society.

# THE ERECTION OF THE MONUMENT TO ELISHA MITCHELL ON MITCHELL'S HIGH PEAK.

*Abstract of an Address delivered before the Elisha Mitchell Society, October 16th, 1888.

WM. B. PHILLIPS.

Thirty-one years ago this summer, on the 27th of June, 1857, the Rev. Dr. Elisha Mitchell, Professor of Chemistry, Mineralogy and Geology in the University of North Carolina, lost his life by falling over a precipice into a pool of water, while engaged in the scientific exploration of the High Peak in Yancey county which now bears his name. After the recovery of the body it was interred at Asheville, N. C., until June 16th, 1858, when it was removed to the summit of the Peak. Several attempts have been made to erect a suitable monument to his memory there, but, from some cause or another, they all came to nought. Upon the death of his daughter, Mrs. E. N. Grant, in 1883, it was found that she had set aside a sum of money to be expended for this purpose. This was increased from time to time by donations from other members of the family, and in the spring of 1888 a sufficient amount was available. At the request

*The full text of this address will be found in the *University Magazine* for December, 1888.

of Miss M. E. Mitchell, of Statesville, N. C., the University assumed control over the undertaking. The deed to the site of the grave was vested in the University, and a committee of the Faculty was appointed to see to the work. This committee consisted of President Kemp P. Battle, Prof. J. W. Gore and Dr. Wm. B. Phillips.

The most suitable structure, perhaps, would have been a monument of rough hewn stone, but owing to the great difficulty and expense of such work at such a place, after mature deliberation and consultation with the surviving members of Dr. Mitchell's family, it was decided to erect a monument of white bronze.

The plans, drawings and estimates were submitted to his family and accepted by them. In May, 1888, the contract was let to the Monumental Bronze Company, of Bridgeport, Conn. It called for a structure of white bronze, of pyramidal shape, 3 feet square at the base, 12 feet high, cast in sections with interior bolts of copper or brass, the heaviest piece not to exceed 140 pounds in weight, the whole to be delivered at Black Mountain Station, on the W. N. C. Railway, by the middle of July, for $400.

The other members of the committee not being able to attend, Dr. Phillips was requested to undertake the work. From Mitchell's High Peak to Black Mountain Station, the nearest available point on the railway, is 19 miles. For the first seven miles from the station the road is fairly good, but from Patton's, at the foot of the cedar cliff on the North Fork of the Swannanoa River, the road for the last 12 miles is a bridle trail. The difference in elevation between Patton's and Mitchell's High Peak is about 3,600 feet, the former being about 3,000, and the latter 6,688 feet high. The average grade is, therefore, about 300 feet to the mile, although for the first 7 miles it greatly exceeds this, being nearly 500 feet to the mile for the first 5 miles. For the first 3 miles above Patton's a tolerable wagon road was prepared, leaving thus 9 miles for the "carry." Three weeks were spent in repairing the trail, which in places had been blocked by fallen timber and badly washed by the torrents of water that rush

down it after every rain. For several miles the trail was a ditch from 1 to 4 feet deep, and from 2 to 3 feet wide, at places intersected by hundreds of roots, at others rendered almost impassable by shelving rocks, so that it was, on the whole, in a deplorable condition. The work on the trail was begun July 18th, and by August 7th was finished to the top of the Peak. The transportation of the monument from the railway was begun August 7th. It was packed in 7 cases weighing in all 1,041 pounds, and was hauled in a wagon 2 miles above Patton's, there unpacked and the several sections, 9 in number, slung on poles and the "carry" was begun. It could have been hauled in the wagon one mile further, but it was found more convenient to send the wagon on with the provisions and tools, and to carry the monument from this point on men's shoulders. All the sections were thus carried for ten miles. In three and a half days after the monument was received at the railway it was laid alongside the grave on the Peak. It weighed about 900 pounds and required for its transportation 13 men and one boy for $3\frac{1}{2}$ days, and two oxen and a wagon $1\frac{1}{2}$ days. The cost of the transportation was $46.96.

The work of quarrying out stone for the foundation was begun Monday, August 13th. The rock on the Peak is a coarse gneiss, very friable and brittle, so that it was found best to get out two blocks and join them in a bedding of Portland cement. The two together weighed about 1,800 pounds, and after drilling in them the necessary anchor holes they were placed in position at the head of the grave and leveled. The bottom section of the monument, weighing 140 pounds, was then anchored to the foundation by eight $\frac{3}{8}$ in. copper bolts, screwed into the metal base and "leaded" into the rock, extending into this 4 inches. The second section was then bolted to the first by eight $\frac{1}{2}$ in. copper bolts fastened from within. The third section was bolted to the second by eight $\frac{1}{2}$ in. copper bolts, and fastened to the bed-rock by four 1 in. zinc bolts, screwed into the section and "leaded" into the rock for 4 inches. The monument is thus anchored to the bed-rock by eight $\frac{3}{8}$ in. copper bolts, and four 1 in. zinc bolts. Each

section was bolted to the one underneath by eight ½ in. copper bolts, all of which fitted fairly well, except a few. All these bolts are *within* the structure, none of them show from the outside. Finally, the cap, weighing about 80 pounds, was hoisted up, and screwed to the eighth section by four ½ in. copper screws with ornamental zinc heads. These heads' being of the exact composition and color of the monument itself, are counter-sunk into the cap, and are barely noticeable.

The last screw was fastened at 4:45 P. M., August 18th, and the monument stood complete. It is severely plain, and has upon it no figure work or ornamental design of any kind. Upon the western side appears, in raised letters, the word "MITCHELL"; on the side towards the grave is the following brief inscription: "Here lies, in hope of a blessed resurrection, the body of the Rev. Elisha Mitchell, D. D., who, after being for 39 years a Professor in the University of North Carolina, lost his life in the scientific exploration of this mountain, in the 64th year of his age, June 27th, 1857."

Below this are the words: "Erected in 1888."

There were no ceremonies connected with the erection of this monument, the family having so requested. Dr. Phillips's address before the University is alone commemorative of the event.

The material of which the monument is made is known as white bronze. It is, in fact, almost pure zinc, which is treated under the sand blast to impart a finely granular appearance, and to cause it to resemble white granite. It does closely resemble this stone. It is practically weather-proof and will not become discolored. It crowns the summit of the highest Peak in the United States east of the Mississippi River, and is probably the "highest" monument in this country which has been made for the purpose and transported on men's shoulders so great a distance.

Some idea of the difficulties connected with this undertaking may be had by bearing in mind that the nearest house to the Peak on the southern side, from which is the best ascent, is 12 miles away. All the tools, provisions, cement, blankets, &c.,

had to be "packed" up from this house, and in many instances had to be brought from Asheville, 32 miles off, by rail for 12 miles, and by horses and men for 20 miles. Not more than 13 men were employed at any one time. The total expense of erecting this monument, inclusive of the first cost, will approximate $750.

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## SOARING OF THE TURKEY VULTURE, (*Cathartes aura*).

GEO. F. ATKINSON.

The problem of the soaring of birds has occupied the attention of different observers for more than a century, and although many of the puzzling manœuvres, and translations, of birds with outstretched wings have been satisfactorily accounted for, there still remain many observed facts unsatisfactorily explained because of the great obscurity in which the problem is veiled. Probably from the earliest dawn of human consciousness man has marveled at, and coveted, the ease with which birds move through the air over vast distances, or rise in a few hours, on motionless wing, from within a few hundred yards of the earth to several miles up in the frigid air of the heavens. During the last century it is noteworthy that, along with the great progress made in the discovery of the laws of motion, this problem has received its due share of consideration, but is *refractory* (if the phrase will be allowed) in the matter of yielding the subtleties of its nature.

It may be interesting, in connection with the presentation of this subject, to briefly review some of the chief discussions during this period.

Old treatises on falconry describe the interesting evolutions of the birds employed in hunting. Huber, in 1784, published at

Geneva a large work in which he describes the curvilinear movements of the falcons. The oblique downward motion "was sufficient to carry it without effort as high as the elevation from which it came." Monsieur Morey* says this is an exaggeration. Observers say birds can sustain themselves in the air by the use of the wind alone. Count d'Esterno, in a remarkable memoir on the flight of birds, says, "Every one can see some bird practicing this method of flight; to deny it is to deny self-evident facts." M. Morey acknowledges that he has seen it, but attributes it to the bird passing alternately from quiet air to a current.

A large part of the discussion in *Nature*, through Vols. VIII—XXVIII, hinged on a misunderstanding between the disputants as to the meaning of the word *hovering;* some discussing the matter from the point of view of *motionless* wings, while others treated it having in mind a slow flapping of the wings, while the bird remained over one place on the earth.

It has long been observed that some soaring birds, after rising to the height of a few hundred feet by flapping their wings, soar around in great circles on motionless wings and continually rise higher and higher until they are several miles from the surface of the earth. S. E. Peal, writing from Sapakati, Sibsagar, Asam, gives an account of this manner of the translation of soaring birds observed by him.† Whenever the birds attempted to soar the wind was blowing. When they began to circle the resultant course of motion was upward, and toward the point of compass to which the current of air was moving. In soaring, when facing the wind, the slant of the wing was such as to cause the birds to rise, but as they turned with the wind the slant of the wing was changed to give a slight downward motion, then again turning to face the wind they rose higher than before, and at each completion of the circle the bird was farther from the earth. In this way the course of the bird through the air was

*Phenomena of flight in the animal kingdom

†Nature, Vol. XXII, p. 10.

spiral, the spire leaning in the direction of the current of air. Lord Rayleigh, F. R. S., was the first to demonstrate, mathematically, how this elevation might be attained under such circumstances without resort to flapping of the wings.* In mid air the bird starts to soar with the momentum acquired by flapping its wings in rising. Say, with outstretched wings, it faces the wind, and gradually rises until the momentum it had acquired is overcome by gravity; it then turns and gradually descends, on a plain oblique to the horizontal, for a short distance. In doing this its velocity is increased from the operation of two causes. The first of these causes is the ever present action of gravity. The second and more important cause requires some introductory remarks. For the sake of clearness let us divide the air into a number of strata parallel with the surface of the earth. During a wind, the different strata of air, starting with the lowest, move with successively increasing velocities. When the bird, facing the wind, has used up the momentum it had acquired, it turns with the wind and passes into a lower stratum of air the velocity of which is less than that of the stratum from which the bird came. In this position the simple act of transposition to a lower stratum of less velocity gives the bird a relatively increased velocity. With this increment of velocity it sails along in the lower stratum, and turning rises into the stratum above. Here another increment of relative velocity is acquired. This enables the bird to rise into a still higher stratum, which moves with greater velocity, and another increment of relative velocity is added.

Suppose the bird was in stratum *b* when it first turned, and that *b* moves at the rate of 10 miles per hour. As the bird has used up its acquired momentum, relatively to the air it is not moving forward. Now as it passes to stratum *a* which has a velocity of 5 miles per hour, the bird acquires a relative velocity of five miles per hour. Now turning and facing the wind it rises into *b* and has a relative velocity of 15 miles per hour,

*Nature, Vol. XXVII, p. 534.

which would be sufficient to carry it to a point higher than that from which it came in stratum *b*: i. e., to *c*. From *c* it would descend into *b* and then rise into *d* and so on.

Lord Rayleigh says he would not have supposed *a priori* that the increment in the velocity of wind at different heights was sufficient, but "some explanation is *badly wanted*."

Hubert Airy* suggests the possibility of vortices of air currents that are constantly receding from the earth, and that the bird may possibly keep in the rear of one of these.

R. Courtenay† states that the Black Vulture of Jamaica in France utilizes currents of different velocities, and may even make use of descending currents to acquire an increase of velocity. In all of this discussion the bird's wing was treated of as if it were a smooth plane. All who have carefully examined a bird's wing know how well adapted it is to produce forward motion of the bird by striking the air perpendicularly. This peculiar adaptation of the wing has been described before quite frequently, but I repeat it here briefly because of the important bearing it has upon the subject. The work of the wing, either flapping or motionless, is to compress air. The work of the elastic air, as it tends to assume its normal condition, works on the wing and produces forward motion. The under surface of the wing is so constructed that air passing to the ulnar (rear) edge meets with little or no resistance, but the air passing to the anterior, or radial, edge meets with great resistance. The radial edge, also, of soaring birds projects downward by the enlargements of the bones and muscles of the *brachium*, *manus*, etc. This also catches some of the air and impedes its movement. The ulnar edge of the wing is made up of the tips of the feathers, called the *secondaries* and *tertiaries* of the wing. These are bent upward by the air which passes this edge. As there is a partial vacuum above the wing, the air pushes forward on this upturned edge as it flows past to fill it.

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*Nature, Vol. XXVII, p. 590.

†*Ibid.*, Vol. XXVIII, p. 28.

Then the action of all the compressed air which passes the ulnar edge, and of all which passes forward upon the under surface of the wing is to cause forward motion of the bird.

Thus we see there are two forces which combine to give a bird, with outstretched wings, forward motion:

1st. *Gravity;* 2d. The *resistance* offered by the wings to the forward movement of the compressed air. The first acts perpendicularly to the earth; the second is subject to the will of the bird, and may act horizontally, or obliquely toward the earth, or obliquely from it. The resultant, however, when the air is quiet, and the bird has no momentum, except that initiated by gravity, is always toward the earth, though in some cases it may be on a plane diverging only slightly below the horizontal. The resultant from the two forces has somewhat the same effect upon the bird that a string, in the hands of a running boy, has upon a kite in quiet air. The bird does not move in the line of the resultant of the two forces, but on a plane somewhere between the resultant and the horizontal. This being true, the additional force, or forces, necessary to carry the bird on a horizontal plane, or a slightly ascending plane, would be far less than many would think.

Many times have I watched the Turkey Vultures in soaring flight, when without flapping their wings they would rise several hundred feet. A case came under my observation in which the bird could not possibly have depended upon successively increasing velocities in the currents of air to supply the force necessary to permit it to rise in an ascending plane. I stood on a hill, and watched a Vulture which was soaring in the valley. The wind was blowing a brisk breeze, but the configuration of the land was such that it is not probable there was an upward current. The remarkable thing is that the bird did not move off with the wind as it rose, but the spiral course was perpendicular. In three circles it rose two hundred feet above my head and then passed off at a right angle to the direction of the wind. I noticed that the bird slowly rocked first on one side and then on the other, especially when it faced the wind. At the time I

thought this was produced by unsteady currents of wind. It is probable, however, that this slow rocking, which I have noticed is quite common with the Turkey Vulture, gives the needed additional force, in many instances, required to ascend. The rocking is equivalent to a slow flapping of the wings.

To show how beautifully the wing is adapted to utilize to the best advantage all of the compressed air, I wish to call attention to a use of the *primaries* of a bird's wing, which up to this time seems to have been overlooked. Indeed, in some cases the special structure which I wish to point out has been regarded by some eminent men as detrimental to the bird, so that they have, in some cases, conceived that the bird resorts to some mechanical contrivance to give to the wing the form which nature neglected to give!

In looking up this question it has surprised me to see how near the Duke of Argyll was to the truth in regard to the use of the *primaries*, and yet missed it at last!

He says: *"Round-ended wings are also almost always open-ended, that is to say, the tips of the quills (*primaries*) do not touch each other, but leave interspaces at the end of the wing, through which, of course, a good deal of air escapes. Since each single quill is formed on the same principle as the whole wing—that is, with the anterior margin stiff and the posterior margin yielding—this escape is not useless for progression; *but the air acts less favorably for this purpose than when struck by a more compact set of feathers.*"

The italics are my own. I wish to emphasize the fact that he concludes a compact set of primaries would be more useful than the *natural separation of the primaries.* I contend that the converse is true, namely, that the *natural separation of the primaries, of a round-ended wing, is more useful for progression than a compact set of feathers would be.* Else, why did nature make them so?

A careful examination of the structure of the primaries of the Turkey Vulture's wing, and the length of the separated portion

*Reign of Law, 5th Ed., pp. 156–157.

compared with the extent of compressing surface of the entire wing, will be sufficient to convince one of the truth of the proposition.

Take a single primary. The rachis (the portion of the quill extending through the length of the feather) is quite stiff, rectangular in cross-section, and projects downward below the vanes of the feather for their entire length. It is also near the anterior edge of the feather and offers effective resistance to all air moving forward on the under surface. The posterior edge of the vane is easily bent upward by the passing air and forms a resistance to the air passing forward over it, in the same manner as the posterior edge of the entire wing presents resistance to the air flowing in to fill the partial vacuum spoken of. About midway of the feather both the anterior and posterior vanes are suddenly narrowed; the anterior one is narrowed close down to the rachis, so that the rachis forms the anterior edge of the feather; the posterior vane is narrowed down to about one-half its width. When the wing is outstretched the primaries are separated from the point of narrowing of the vanes to their tips. The development of the peculiar shape of the primaries, as described, was for the purpose of admitting their separation at this point. The distance from this point of separation to the tips of the primaries is about eight inches; from the same point to the body of the bird is about two feet. The depth of the wing from anterior to posterior edge is about one foot. When the bird is soaring the compact portion of the wing, a surface two feet by one foot, compresses the air. The compressed air tends to rush out in three directions, *cephalad* (anteriorly), *caudad* (posteriorly), and *distad*, *i. e.*, toward the outer end of the wing, at a right angle to the direction the bird is moving. All of the air which rushes out at the distal end of the wing passes upward between the separated primaries, and each one utilizes the air next to it in forward motion. Did these feathers form a compact surface, the only portion of air utilized would be the small amount passing by the anterior primary and the posterior outstretched primary. All the remainder would pass out at the tips of the primaries, and

push toward the bird. The corresponding amount of air would be lost at the tip of the other wing, and would work to counteract the sideways thrust of the first one mentioned. This amount of air beside being lost would actually work to the annoyance of the bird. Work would be performed only by one primary, whereas, with the primaries separated, *all* work, and *all* of the air is utilized. The value of the separation can be seen when we consider the amount of air which passes out at the end of such a large compressing surface, and especially when we note in soaring the distal ends of the bird's wings are slightly elevated.

It is difficult to conceive how Mr. Trowbridge could mistake this natural emargination of the primaries of soaring birds* for a *wearing* produced by a supposed artificial overlapping of these primaries to which the bird had recourse in soaring. Were it possible for such a bird to lock its primaries into a compact surface, it could not soar so readily as when the primaries were in their natural position.

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## OF THE THREE CRYSTALLOGRAPHIC AXES.

WM. B. PHILLIPS.

The study of Crystallography is considered by most young students as something of a bugbear. This view of a really beautiful study is perhaps not unnatural. So short a time is devoted to it in most colleges that opportunity is not given for the proper unfolding of it.

During the course in Mineralogy as offered in the University of North Carolina for the past two years the greatest difficulty that has been met is in the almost total lack of training in the

*Science, Nov. 18, 1887, Jan. 6, 1888.

imagining of lines that do not exist, the so-called crystallographic axes. Without a clear conception of this fundamental principle it is well-nigh impossible to impress upon the mind of the student the idea of a crystal.

The following scheme, after mature deliberation and consultation with Dr. Chas. Phillips, Professor Emeritus of Mathematics in the University, was adopted, and found to be of considerable help in directing attention to these lines. It is given here in the hope that other teachers, not only of Mineralogy but of Mathematics as well, may find it of value.

In every crystal there are three imaginary lines termed crystallographic axes. These three axes are either

(1). All of one length, or

(2). Two of one length, and the third of another, or

(3). All three of different lengths.

Under (1). we may have

a. Each perpendicular to the plane of the other two.

b. One perpendicular to the plane of the other two, which (two) are oblique to each other.

c. One oblique to the plane of the other two, which (two) are perpendicular to each other.

The same is true under (2). and under (3).

Adopting the following notation

| | | | | |
|---|---|---|---|---|
| 1a | 1b | 1c | 1d | |
| 2a | 2b | 2c | 2d | |
| 3a | 3b | 3c | 3d | we have |

1a=Isometric system

1b has no crystal system

1c " " " "

1d " " " "

2a=Tetragonal system.

2b=Hexagonal system, but as the 60° axis may lie on either side of its principal this system has four axes instead of three.

2c has no crystal system

2d " " " "

3a=Rhombic system
3b=Monoclinic system
3c has no system
3d=Triclinic system.

By this conception we exclude from the possibilities of crystal form 1b. 1c. 1d. because equality of length among the three axes is always connected with rectangularity of intersection. We exclude also 2c. and 2d. because with axes of two different values no other conceptions are crystallographically possible than that of rectangularity of intersection, as in the Tetragonal system, and obliquity of intersection as in the Hexagonal system. Lastly we exclude 3c. because with axes of three different values we do not have, in crystals, one of the axes oblique to the rectangular intersection of the other two.

(Compare *V. v. Lang*, Lehrb. der Krystallog. S. 99; *Sohncke*, Entw. einer Theorie der Krystallstructur, Leipzig, 1879, and an article by Sohncke, Ann. d. Phys. u. Chem. Bd. 132).

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## CHLORINATION OF AURIFEROUS SULPHIDES.

E. A. THIES.

Chlorination is the name applied to the treatment of oxidized gold ores with free chlorine, and the success of the process depends upon thoroughness of the previous oxidation.

The material employed is auriferous pyrite containing also from one to two per cent. copper in the shape of sulphide.

At the Phœnix Mine, in Cabarrus county, the gangue is quartz with varying amount of heavy spar (Barite).

The ore from the mine is passed through a Blake crusher and stamped in ordinary ten stamp mill for the purpose of pulverizing it to 40 mesh and saving most of the free gold, which is always present. The shines are passed over True Vanner con-

centrators for the purpose of separating the sulphurets from the gangue; the proportion of sulphurets to gangue varies from ten to thirty-five per cent. The concentrates contain from 25 to 30 per cent. sulphur, with a value of $20 per ton, and contain from 1 to 2 per cent. copper, with small amount of silver. These are dead roasted in a revolving hearth furnace, with frequent rabbling; each furnace will roast about one ton in twelve hours. It is upon the thoroughness of this roast that the success of the succeeding chlorination depends; it is the purpose to free the ore as far as possible from sulphur compounds. Assay value of roasted ore is about $30 per ton. The thoroughly roasted ore is then charged into a lead-lined iron cylinder, 42 in. x 60 in., provided with discharge valve, with heads securely bolted on each end; by suitable gearing these cylinders are caused to revolve horizontally at the rate of 20 revolutions per minute. Charge for each cylinder is as follows:

| | |
|---|---|
| Roasted ore, . . . | 1 ton. |
| Water, . . . . | 100 to 125 gallons. |
| Bleach, . . . . | 40 to 50 lbs. |
| Sulphuric acid 66°, . . | 50 to 60 lbs. |

The valve is closed, the cylinder set in motion and continued so from 8 to 10 hours. The chemical action within the cylinder is the evolution of free chlorine by the action of the sulphuric acid on the bleach with formation of sulphate of lime; the free chlorine attacks the oxide of copper formed in roasting, with formation of chloride of copper, the free gold with formation of gold chloride and some of the oxide of iron with formation of iron chloride. It is in the chlorinator that the necessity of a dead roast becomes apparent, for the action of sulphuric acid upon the undecomposed sulphides would yield hydrogen sulphide and precipitate the gold from the gold chloride and any ferrous sulphate left in the ore would likewise cause a precipitation of the gold. In neither case, then, could the gold be leached out in the form of chloride.

It has been found by actual practice that it is better to divide the charge of bleach and acid and add them at least in two

separate portions, maintaining, however, the proportion between them.

After the gold has been converted into soluble chloride, which generally happens, as before stated, in 8 or 10 hours, the chlorinator is discharged into the filter.

The filters are wooden boxes 6 feet wide, 8 feet long, 1½ feet deep, lined with lead and filled for 6 in. to 7 in. with gravel, as follows: A false bottom is laid, provided with numerous small outlets; this false bottom was formerly made of wood, but is now made of perforated tiles. On it is placed first a layer of very coarse gravel about 1 in. in thickness, and so on up to the height of 6 in. to 7 in., the material of each succeeding layer being smaller than that underneath, the topmost layer being fine sand. Made in this way a filter will last from 12 to 18 months without being renewed. The material discharged from the chlorinator is a mixture of solid and liquid substances, the solids being oxide of iron, gangue, sulphate of lime and silver chloride if any silver is present. The liquid being aqueous solution of the chlorides of gold, copper and iron with some free sulphuric acid, the filter retains the solids, while the liquids drain away in suitable vats. The filter is washed until all the gold chloride is washed out, which is ascertained by observing whether the last filtrate reacts with copperas solution. Time required for filtering and washing a charge is from two to three hours, and amount of wash-water used is about three hundred gallons; the leached ore on filter is thrown away, unless by panning it is found that the free gold has not been dissolved; in this case it is re-chlorinated, if the amount is sufficient to warrant the expense. If much silver be present, it will be on the filter as chloride and can then be leached out with "hypo," and precipitated with hydrogen sulphide. The gold solution is stored in lead-lined wooden tanks holding about 1,800 gallons. A sufficient quantity is from time to time run into precipitating vats lined with lead and then precipitated as metallic gold by ferrous sulphate. Thrown down in this way gold is a very fine brownish powder and requires about four days to settle.

When the gold is fully settled, the supernatant liquor is run off into tanks in which scrap iron is thrown for the purpose of recovering the copper in the solution. The gold precipitate is scraped up, washed carefully with hot water and thrown on paper filters. It is dried in stove and melted down in the usual way into bullion. As a rule the auriferous sulphides in North Carolina contain but little silver, and the bullion obtained by this process is from 990 to 996 fine.

By this process 90 per cent. of the assay value in gold is guaranteed; the actual return is never lower than this and for the most part is higher.

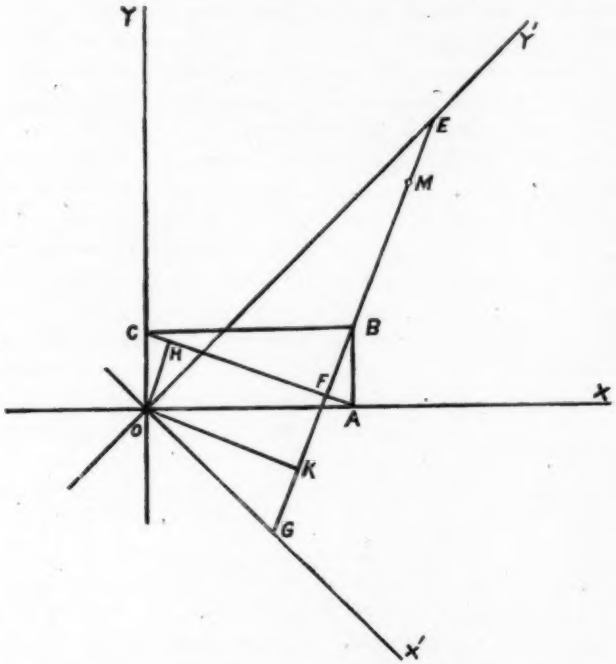
No other process which has been applied to auriferous sulphides in this State has yielded such excellent results, and it is hoped that a useful future is in store for it.

Metallurgical Laboratory,
University of North Carolina.

# A METHOD OF FINDING THE EVOLUTE OF THE FOUR-CUSPED HYPOCYCLOID.*

R. H. GRAVES.

The following is a method, based on the Theory of Roulettes, of proving the well-known result, that the evolute of a four-cusped hypocycloid is also a four-cusped hypocycloid:




Let AC=a move with its extremities always on the rectangular axes Ox and Oy. The envelope of AC is the four-cusped hypocycloid.

*Published also in the "Annals of Mathematics."

Complete the rectangle OABC; draw Ox′ and Oy′ bisecting the angles between Ox and Oy; draw EBFG perpendicular to AC; draw OK and OH parallel and perpendicular to AC; let CAO=p.

B is the instantaneous centre, BF is normal to the envelope of AC and its envelope is the required evolute.

ABF=p, FBC=90°—p, BEO=45°—p, OGK=45°+p

OK=HF=a—2 a $\sin^2$p=a cos 2 p.

EG=OG cosec BEO=OK cosec OGK cosec BEO

=a cos 2 p cosec (45°+p) cosec (45°—p).

Hence, by reduction EG=2a.

Since EG is of constant length, and its extremities move on two rectangular axes, its envelope must be a four-cusped hypocycloid, which is the required evolute.

*Remark.*—If M is the point where EG touches its envelope, BM=BK. For, at the point (x, y) of the curve $x^{\frac{2}{3}}+y^{\frac{2}{3}}=a^{\frac{2}{3}}$, the radius of curvature is 3 $(axy)^{\frac{1}{3}}$ and the perpendicular from the origin on the tangent is $(axy)^{\frac{1}{3}}$.

Or, it follows from the formula connecting the segments into which the radius of curvature of the hypocycloid is divided by the instantaneous centre. (See Williamson's *Differential Calculus*, Art. 281).

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## *MICA MINING IN NORTH CAROLINA.

W. B. PHILLIPS.

Modern mica mining began in North Carolina in 1868–'69. Some little work was done in 1867, but beyond opening two or three pits, and getting out several hundred pounds of fine mica, not a great deal was accomplished. Reference has already been made† to the fact that some of the mines had been worked by

*This paper has appeared in the Engineering and Mining Journal.

†W. C. Kerr, Engineering and Mining Journal, Vol. XXXI, No. 13, p. 211.

the prehistoric inhabitants of the country, who disposed of the mica, in part at least, to the mound-builders.* These "old men" were possessed of considerable skill, not only in the location of good deposits, but also in the extraction of the mica. The first is proved by the fact that by following their "leads" modern miners have found the best mica, and the second by the fact that sheets of mica of considerable size have been found in old mounds. Although some evidences of the use of other than stone tools have been found in old drifts, the principal method used by these "ancients" was fire-setting.

They did not penetrate into the hard rock to any great extent, nor is it likely that they sank shafts. Curiously enough, the method employed for opening the deposits in those days, viz., by open trench, is that at present used in New Hampshire. Shaft-mining, vertical and underlie, is the exception in New Hampshire; it is the rule in North Carolina. In 1867 the Hon. Thomas L. Clingman, of Asheville, N. C., was induced by some New York mica dealers to undertake investigations in North Carolina for mica. Small sheets were then selling at $8 per pound, and the supply was uncertain. He began operations in Cleveland county, and found some good mica, which was shipped to New York. This was late in 1867, or early in 1868, and is the first instance I have been able to find of the prosecution of mica mining, as a regular business, since the days of the Indian mound-builders. Some work was done at this time in Burke and Rutherford counties, also, but with no very satisfactory results. He then transferred his explorations to Yancey and Mitchell counties, selecting as the best spots what was afterwards the Ray mine, in Yancey, and the Silvers or Sink Hole, and the Buchanan or Clarissa mines in Mitchell.

The first work done at the Silvers mine was not, however, in searching for mica, but for silver. It was known that at this place were great pits and trenches, amounting in all to some 1,800 feet in length, and in places 20 feet deep, with large trees

*Foster, Prehistoric Races of America, pp. 191 and 270.

grown up on the debris, and with every appearance of age. The very memory of these old miners had passed away, and nothing was left to them but their pits and trenches here, and pieces of mica found in the Indian mounds in the Ohio valley. Tradition, always busy with the unknown, had determined that these workings had been undertaken for silver. Some specimens of the rock from the Silvers mine were pronounced by the ubiquitous practical miner to resemble some rich silver ores from Mexico, but the assay proved them to be worthless. The first work done at the Silvers mine was for silver, and it was not until it was found that there was no silver that attention was turned to the mica.

One at least of his New York friends had accompanied Clingman to Yancey county to search for mica, but did not think well enough of the enterprise to continue in it. Clingman, however, continued the work of mica mining at the Silvers mine, and obtained several hundred pounds of fine mica.* Being called away by more pressing business, he instructed his foreman to collect the mica and store it away. This, however, was not done, and several large blocks were left on the ground. A stock-drover passing that way with his wagon took one of these blocks to Knoxville, Tenn. It was seen by J. G. Heap, of Heap & Clapp, dealers in stoves and tin-ware, who at once recognized its value. He and his partner disposed of their business in Knoxville and went at once to Mitchell county, N. C., and began mica mining.† This was in 1869. From that time and for several years they conducted a very profitable business, realizing for some of the mica, as Mr. Heap himself assured the writer, as much as $11 per pound.

Heap & Clapp first worked the Silvers mine, and by following the old leads obtained large quantities of excellent mica. They cut new trenches, ran an adit in and sank several shafts. They also worked the Buchanan or Clarissa mine, by shaft and

*Thos. L. Clingman, priv. com., October 25th, 1887.

†C. H. Wiley, U. S. Treas. expert, Internal Commerce of the U. S., 1886, p. 235.

adit, and found it equally good. Several other mines were opened and worked, as the Deake and Flat Rock. As local experience was acquired (the *sine qua non* in mica mining as in every other kind), they extended their operations, so that up to 1882 of the 400,000 pounds obtained Heap & Clapp must have mined by far the greater part. The average spot value of cut mica then was about $2 per pound, some, however, selling as high as $11. Even at $2 the total value of the mica up to 1882 would be $800,000. As to the profits, no very definite information can now be given. In 1880 the total real and personal capital invested in the North Carolina mica mines was $6,900, and the value of her product $61,675*—every dollar invested returned $8.93 I cannot say of my own knowledge whether these figures can be accepted or not. If true, if they can be taken as fairly representing the capital and yield, they reveal a most remarkable state of affairs. The waste in mica alone, as we shall hereafter see, is from 85 per cent. to 95 per cent. in mica mining. That any mining operation utilizing at most only 15 per cent. of the stuff brought to bank should return $8.93 per $1 invested is simply incredible. It is stated† that some of the free milling gold ores of Dakota are worked at a profit on $2 a ton, that some steam-tin works in Cornwall yield only two pounds of black tin per ton,‡ and that the pay-dirt at the Eureka claim, near San Juan, California, gave a profit on three cents per ton.§ So far as the refuse matter is concerned these examples show there are places where it far exceeds the North Carolina mica mine waste. But it is not stated that there was anything like such a profit as is reported from the mica mines. It is so great as to be incredible. We shall hereafter see that the New Hampshire mines in 1880 yielded twenty cents per $1 invested, which figure, while indeed somewhat low, is perhaps about right.

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*Tenth U. S. Census, Vol. XV, p. 843.

†Report of the Director of the Mint on Precious Metals, 1884, p. 251.

‡J. A. Phillips, Mining and Metallurgy of Gold and Silver, p. 160.

§Collins, Metal Mining, p. 56.

There has always been a curious reticence on the part of the North Carolina mica miners and dealers, and a corresponding difficulty in acquiring correct information. While indeed there are some notable exceptions (and to these I would return my warmest acknowledgments of their kindness) they serve but to make the background all the more obscure. I am often at a loss to know to what this reticence is to be ascribed. There are no more hospitable people in the world than the inhabitants of the mountains of Western North Carolina, nor any upon whose willingness to aid one in any laudable undertaking more assurance could be placed. And yet when it comes to mica mining they are reserved to the last degree, and it was only after repeated visits to the mines, and extended acquaintance among the miners, that I was able to acquire much information concerning the business.

It is proposed in this paper to describe this business; the geology of the mining districts; the formation of the veins; dressing the mica; the percentage yield of cut mica from block mica, etc., etc.

The success that attended the operations of Heap & Clapp in 1869 in Mitchell county soon induced others to enter the field. The profit was large, the work comparatively easy and the mica abundant. The Indians (I use the term for lack of a better) had shown that good mica was to be had with very little expense or trouble. The whites were indeed for some time in doubt as to the purpose of the old works, but as on following the trenches and re-excavating the old diggings they found only mica, they soon came to understand this mystery. Had it not been for the prehistoric operations much time and money would have been expended on searching for the true veins. But, as it was, the miners of 1869 took their cue from the miners of 1500–1600, and with their modern appliances—rude, indeed it may be, but far superior to those of their predecessors—they carried on the business vigorously. It was not long before Mitchell and Yancey counties were dotted with prospect holes of more or less promise. The Ray mine, Westall, Joe Gibbs, Young, Baily

Mountain and others in Yancey county, the Pizzle (now Cloudland), Deake, Flat Rock, Mart Wiseman (famous for rare minerals) and others in Mitchell county were opened and worked. The fever spread, and in the counties of Buncombe, Haywood, Jackson and Macon other mines were added to those already in operation. Strange stories were told of the curious minerals found in some of the mines. J. G. Heap, the pioneer of regular mica mining, and one of the shrewdest of men, told me that he has seen masses of "uranium ore" as large as his head imbedded in perfectly white kaolin. Not being then apprised of its value (in 1869 some parts of Mitchell county were on the confines of mineralogical knowledge) he paid no especial attention to it, and it was thrown on the dump and lost. He knew better before long, as did the others, and now uraninite and gummite, etc., are saved. A few years ago, watching the emptying of the water bucket at the Flat Rock mine, I was able to secure some very handsome specimens of uraninite and gummite. Several old miners standing near remarked that when the mine was first opened those minerals were much more common and in much larger pieces. The first miners mined for mica and paid but little attention to other minerals, and they very likely threw on the dump many interesting and valuable minerals as not being their *point d'appui.*

Mitchell county has been the scene of the most extensive operations, the deepest mines are located here, and by far the greater amount of mica sent to market from North Carolina has been obtained here.

The county lies between the Blue Ridge on the east and the Smoky Mountains on the west, being a part of the great western plateau between these two ranges. Its average elevation is not far from 3,500 feet, and it slopes gradually from east to west, the highest point, Roan Mountain, lying on the Tennessee boundary. The eastern boundary, the Blue Ridge, attains a height of 5,228 feet in the Sugar Mountain, while Roan Mountain on the west rises to a height of about 6,400 feet. There is on the whole, therefore, an upward slope towards the west. Some in-

termediate points, however, are much lower than the Blue Ridge. Thus, for instance, Bakersville, the county-seat and the mining town for the district, is 2,550 feet, while the Watauga River, at the State line, is 2,131 feet. The most productive mines in Mitchell county lie within ten miles of Bakersville, on the east, north-east, south and south-east, at an elevation from 3,000 to 4,000 feet.

## GEOLOGY OF THE VEINS.

The geology of Mitchell county has been described as follows: "Another considerable area of Laurentian rocks is found beyond the Blue Ridge,* occupying most of the mountain plateau between that and the Smoky Mountains, and in the places constituting the materials of these chains. The rocks are foliated for the most part and consist of indefinite alternations of metamorphic strata, gneiss, hornblende, feldspathic and micaceous schists, and occasionally chloritic and talcose slates."

According to the same authority† the roughly shaped hills that occur through Mitchell county, scattered irregularly, and in close connection with the greatest dislocations of the strata, are to be referred to a very low horizon. He identified them as chrysolyte ledges (dunite). Though they occur very frequently in close association with the mica-bearing rocks proper, the connection between the two has not yet been made out. These chrysolyte or dunite ledges occupy the middle portion of the plateau, and are sometimes "nearly a mile long and several hundred yards wide."

It is still, I believe, an unsettled question whether this plateau is Laurentian or Lower Silurian, Cambrian. The absence of all traces of animal or vegetable remains (unless, indeed, graphite be considered vegetable remains), the well-nigh exclusive occurrence of the older crystalline rocks, such as hornblendic and actinolytic rocks, schists, syenites, and more or less porphyr-

*W. C. Kerr, Geol. of N. C., Vol. I (1875), p. 128.
†*Idem*, p. 129.

oidal granites, and the extreme dislocation of all the members of the series, would seem to indicate an age beyond the Silurian. It would require patient and long continued observation, based chiefly on stratigraphical and petographical relations, to settle this obscure problem. It is known, however, that the mica-bearing rocks of the plateau between the Blue Ridge and the Smoky Mountains do not cross the Smoky Mountains, except sporadically, and then only for a short distance. On the western side of the Smoky Mountains, in Tennessee, we meet with the Silurian, but as it does not here carry mica, though only a few miles from the North Carolina mica zone, the assumption that the "mica zone" occurs in rocks older than the Silurian is somewhat strengthened, be that age Huronian or Laurentian.

Assuming, therefore, for the present that the mica occurs in the very oldest rocks, we may inquire as to its immediate congeners.

A mica vein is only a vein of very coarse granite, in which the feldspar, quartz and mica have crystallized on a large scale. It differs from ordinary granite chiefly in this respect, that while in granite the crystallizing forces have, in a measure, interfered with each other in a mica vein, each has had, so to speak, free play. The difference between the two can best be conceived by imagining the ingredients of granite magnified several hundred, indeed, several thousand, times. The crystals of mica in granite seldom attain a greater size than one-sixteenth or one-fourth inch across; a single mica "block" from Mitchell county made two two-horse wagon loads and could not have weighed less than 2,000 pounds! A single block of "A" mica from the Mart Wiseman mine in Mitchell county was 6 feet long and 3 feet wide. The crystals of feldspar in granite are seldom larger than one-sixteenth or one-fourth inch across. A single feldspar *crystal* from the Balsam Gap mica mine, Buncombe county, weighs 800 pounds, and is now in the State Museum at Raleigh. A piece of a feldspar crystal, now in the possession of the writer, obtained from the Deake mica mine, Mitchell county, weighs 30 pounds. It originally weighed 500 pounds, but was unfortu-

nately broken by careless handling in the mine. Although no large quartz crystals have been obtained from these mines, large masses of crystallized quartz (generally the darker colored sorts) are constantly met with. The accompanying small red garnets are generally sprinkled through the quartz, and not through the mica or feldspar.

### FORMATION OF THE MICA VEINS.

The free play which the crystallizing forces enjoyed between the enclosing walls of the vein is one of the remarkable phenomena to be observed in these mica mines. Nowhere else can this be seen on such a scale. The development of a single mineral in a vein is not uncommon, but the wholesale crystallization of all the chief constituents of a vein is very infrequent. It is worthy of notice here that in a mica vein these constituents are highly siliceous. Taking the percentage of silica in the quartz as the standard, we have the percentages of silica as follows:

| | Per cent. |
|---|---|
| Quartz | 100 |
| Feldspar (orthoclase) | 64.72 |
| Mica (muscovite) | 45.75 to 51.80 |
| Garnet | 35.00 to 52.11 |

Garnet is here included because, although it does not occur in large crystals, it is nearly always present, and in considerable quantities, sprinkled in the quartz. This, so to speak, excessive extension of the crystals would seem to imply that they met with but little resistance, or that the resistance was easily overcome. W. C. Kerr was of the opinion* that many of the irregularities of these veins, in form, size and position, were due to the efforts of the vein matter to intrude itself. These irregularities, however, seem to me to be chiefly due not to this cause but to the original fissuring forces. It may indeed be true that in the attempt to *crystallize* the vein matter caused some irregularities in the shape and size of the fissure, but this is a force different in

*Engineering and Mining Journal, Vol. XXXII, No. 13, p. 211.

kind and degree from the intrusive force referred to. In the work of intrusion the temperature of the intruding mass would have been lowered. As this process went on, and more and more work was accomplished, the temperature would tend more and more towards the point at which the crystallization would set in, unless a new source of heat was at hand and available. The amount of heat given out by the solidifying vein matter would of course be the same as was absorbed by it in first assuming the liquid state. Whether the amount of heat equivalent to the effect of intrusion would be less than equal to or greater than the amount thus set free is a question upon which I do not now propose to enter. The subterranean forces causing the ascension of the vein matter in a liquid or semi-liquid condition could have forced it into the various ramifications of the fissure and have thus left it to follow its own crystallizing tendencies. That there was little or no hindrance to it in passing to the solid state is shown by the size of the resulting crystals. The great and extended irregularities in these veins I would therefore attribute primarily to the original fissuring forces, the small and more local ones to local causes, among which may be included local intrusion and local crystallization.

At whatever point within the fissure we consider the vein matter, whether before or after crystallization, it will appear as completely filling it. A "horse" within a mica vein is seldom met with. There is one at the Sink Hole mine. Here the inclosing rock is mica schist, and the following succession of substances has been observed from wall to wall:* 1st, mica; 2d, a "horse" of mica schist; 3d, smoky quartz; 4th, mica; 5th, smoky quartz; 6th, a "horse" of mica schist; 7th, mica.

The deposit of mica between the "horse" and the wall is narrow, but yields good mica. The greater part of the mica in the vein crystallized first, and probably in this process tore off a piece of the wall, the space left by it being subsequently filled with mica. The pieces torn off are somewhat more decomposed than the original walling.

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*W. C. Kerr, *ut supra.*

The direction taken by the mica crystals is not without interest. As a rule the plane of crystallization, parallel to laminæ of the mica, is more or less inclined to the line of strike, being frequently perpendicular to it, so that the mica on being uncovered resembles a pile of thick planks laid flat on the sole of the level. I do not recall an instance of a contrary arrangement, *i. e.*, of a parallelism between the plane of lamination and the line of strike. The tendency is strongly the other way.

An interesting question here is whether the mica, feldspar, quartz, garnet, etc., existed as such within the vein, and had only to segregate themselves by crystallization, or whether they are to be regarded as forming within the liquid mass highly complex silicates, which crystallized according to the chemical affinity of their constituents under the existing circumstances. According to the first view, the mica probably existed as $H^4K^2(Al^2)Si^6O^{24}$, the feldspar as $K^2(Al^2)Si^6O^{16}$, the garnet as $\overset{II.}{R^3}(\overset{VI.}{R^2})Si^3O^{12}$, where R = Ca, or Fe, or Mg, and $(R^2) = (Fe^2)$ or $(Al^2)$, and the quartz as $SiO^2$. They existed *as such*, and had only to crystallize to become visible.

According to the second view, the potash, alumina, lime, magnesia, iron and silica were all in a state of aqueo-igneous fusion together; some of the potash and alumina lay hold of the requisite amount of silica and became mica; another portion of the potash and alumina and silica formed feldspar, etc.; the portion of silica not needed for these compounds finally crystallized as quartz. In neither case could crystallization occur until the critical point (congelation point) for each substance was reached.

The various chemical elements in the vein matter would at the moment of crystallization have affinities influenced by the temperature, pressure, etc., and these affinities might or might not be the same as at ordinary temperature and pressure. That a high heat does influence chemical combination is a fact too well known to be more than re-stated. Thus it is well known that at a glowing heat oxygen has a greater affinity for carbon than for either hydrogen or iron, strongly as it tends to combine with these two elements. The chemical affinities existing between a

number of elements under the circumstances of heat and pressure in a liquid mass from which mica, feldspar and quartz were afterwards to crystallize might well be different from what would obtain if the limiting circumstances were withdrawn. Potash, alumina and silica do not combine at ordinary temperatures, nor do lime, iron and silica.

Whatever the affinities between these substances might have been before crystallization, when this process was once established it went on to form perfectly definite compounds. Which one crystallized first is not so quickly said. From evidence now in my possession I am inclined to believe that the mica crystallized first. I was led to this conclusion, not by theoretical considerations, but by having found in a mica vein a piece of quartz having on it evident impression of the edges of a block of mica, forming a sort of pyramid with microscopic steps; inclosures of quartz between the laminæ of mica, the quartz being almost as thin as the mica; inclosures of feldspar in mica also very thin, and lying pressed between the mica sheets.

These three circumstances taken in conjunction would seem to indicate a crystallization of the mica prior to that of the quartz or feldspar. A synchronous crystallization would have given a mass more nearly resembling granite, in which each substance has interfered with the other. So far then as the moment of crystallization is concerned, a mica vein differs from granite in having suffered a succession of crystallizations instead of synchronous crystallization. Had the mica, feldspar and quartz all crystallized at the same time, there is no reason why there should not have been granite in the fissures instead of a mica vein.

It will appear from the preceding discussion that a mica vein is only a vein of very coarse granite in which the forces of crystallization have had comparatively free play. The resulting crystals are of great size, and have interfered but little in each other's development. So far as the texture of the vein is concerned it is as different from that of ordinary granite as a collection of single crystals of large size is from an agglomeration of crystals of small size. The almost exclusive occurrence of well

crystallized quartz would seem to indicate a solidification from a fluid or semi-fluid mass of aqueo-igneous origin, rather than from a fused mass of purely igneous origin.

For the production of such large crystals the mass must have solidified very slowly, and have met with but little resistance. The view that the dislocation of the inclosing strata was in part due to the intrusion of the vein can be accepted only with caution. What are the inclosing rocks, and how are they related to the mica veins?

The inclosing walls are for the most part dark gray mica schists, more or less hornblendic, somewhat decomposed towards the surface but becoming harder further down. At some mines, for instance, the Presnel in Yancey county, and the Pt. Pizzle (Cloudland) in Mitchell county, the inclosing rock has more of the appearance of a schistose gneiss. But even where it is most gneissic it is still highly micaceous and hornblendic. An interesting occurrence is at the Balsam Gap mine, in Buncombe county, on the Black Mountain, at an elevation of 3,500 feet.* Here the walling on both sides is a slaty gneiss, which offered such resistance to the fissuring force that the fissure stopped short of the surface, and there lies above the mica a capping of gneiss. It may be, of course, that the erosion there was not sufficient to remove the capping, while at other mines now showing outcrops of mica veins the rock did not oppose such resistance. Because a mica vein outcrops now we may not be warranted in assuming that it always outcropped. In cases where the original outcrop has been covered over by newer formations the explanation is simple; but where the vein never reaches the surface at all, as probably at this mine, it is not so simple. Gaetzschman† would seek to explain such an occurrence by supposing a considerable lapse of time between the opening and the filling of the fissure,

*Figured and described by W. C. Kerr, Engineering and Mining Journal, Vol. XXI, No. 13, p. 212 and Trans. Amer. Inst. Min. Engs., 1880.

†Auf-und Udtersuchung Nutzb. Mineralien, Leipzig, 1865, p. 92, where many similar occurrences are noted. Compare also Von Cotta, Erzlagerstätten, 1 Th., 1859, p. 118. Grimm, Lagerst. der Nutzb. Miner, 1869, p. 160.

especially if fragments of the walling were included in the vein. That such fragments are thus included in mica veins will appear from the discussion in Article II of this series.

The inclosing rocks, whether micaceous schists, slaty gneisses or gneissoid micaceous schists, have a general strike toward the north-east, and a general dip toward the south-east, at angles varying from 40 to 90 degrees. The mica veins share these characteristics more or less completely, and are hence bedded veins.

So far as known the walling is the same on both sides of the vein. Contact deposits do not occur in this region as they do at the junction of sandstones and schists near Mts. Lincoln and Bross, in Colorado.* When the Silvers or Sink Hole mine was first opened in 1868–'69, the upper part of the vein was a decomposed feldspar; at 20 feet depth this passed into granite, and at 60 feet the vein narrowed so that work was suspended for a while.† The vein was afterwards found to widen again, while still in granite.

Good crystals of mica, sometimes of several inches in dimension, have been observed in Prozoic granites of the Sweetwater Districts, Idaho,‡ as also in the granite of the Black Hills.§

At this latter locality they form about 5 per cent. of the granite, this proportion, as will hereafter appear, being somewhat below the average yield of "cut" mica from North Carolina "block" mica. It is interesting to note, also, that the crystals of mica in the granite occur in bunches or segregations, a phenomenon likewise characteristic of some Mitchell county mines.

The inclosing rocks in North Carolina have suffered many and great dislocations; they are bent, curved and twisted in a variety of ways without, however, giving rise to faults in the vein. The irregularities of the veins, therefore are those of form, size, strike and dip, rather than of position. It must not be forgotten that the rocks of this district have suffered enormous erosion

*U. S. Geol. and Geogr. Survey of Colorado, 1873, p. 269.

†D. A. Bowman, Mitchell county, priv. com., Nov. 5, 1887.

‡U. S. Geol. and Survey of Idaho and Wyoming, 1877, p. 158.

§U. S. Geol. Survey, Black Hills, 1880, p. 70.

and denudation. They are among the very oldest rocks of this continent, and probably have not been submerged since the Cambrian period. We have in them the unmoved remains of the old crystalline rocks, and what is now exposed to our view was formerly overlaid by rocks of the same age. When this plateau was elevated, with its border of high mountains on every side, the fissures now filled with the mica veins were opened. The fissures most naturally followed the line of least resistance. Where this coincided with the line of bedding, a true bedded vein resulted. Where, on the contrary, it ran somewhat transverse to this line after having followed it for some distance, the vein assumed more of the character of a lode. This seems to me the true explanation of an occurrence sometimes met with, as at the Pizzle mine, where the vein, after coinciding in strike and dip with the inclosing schists, suddenly breaks across the stratification and changes its dip.

The mica veins in North Carolina are true fissure veins, differing in this respect from the mica veins of New Hampshire, which, according to N. S. Shaler,* "appear to be obscure beds closely following the general run of the apparent bedding that characterizes the granites in this part of the country."

Hitchcock† ranks the Grafton mica veins in the gneissic series, and says that valuable deposits are found only within the fibrolite area (mica schist with fibrolite, one of the supposed divisions of the Montalban Group). This fibrolite area lies in between the two great areas of porphyritic gneiss, very well developed between Rumney and Hebron.

Of the influence of the walling on the quantity and quality of the mica but little is known. My own investigations on this subject have not yet led to any definite conclusions. Some of the more experienced miners in Mitchell county say that both the quantity and the quality of the mica depend upon the character of the walling and of the vein, but the lack of careful and

*Tenth U. S. Census, Vol. XV, p. 833.

†Geol. of New Hampshire, Vol. I, 1874, p. 26, and Vol. III, part V, p. 90.

long-continued observations, conducted in a methodical and scientific manner, preclude the formation of definite and reliable opinions. There are so many accessory circumstances that influence the quality of the mica—such, for instance, as the width of the vein, the presence of flat and curved mica, of crystallized feldspar, etc., that the time has not yet come for expressing an opinion. These circumstances may depend more or less upon the character of the walling; but if so, it is not known just what the connection is. The same may be said as to the influence of width, depth, dip, strike, and accompanying minerals.

Below the zone of atmospheric influences, rarely extending below 20 feet, and sometimes not below 10 feet, the vein becomes more solid, and the quality of the mica improves. The width of the veins varies widely, from 3 to 40 feet, sometimes in the same mine varying from 3 feet to 20 feet, as at the Presnel mine, Yancey county. Nipping of the vein is a common occurrence, occasionally to almost entire obliteration. It has frequently happened that one set of miners have quit work on account of a "nip," and another set at a subsequent date have prosecuted the "driving," and found good mica within a few feet. The "stringers" that make off from the main vein penetrate into the wall-rock at various angles, and though narrow sometimes yield fine mica.

The occurrence of well crystallized feldspar is held to be a sure indication of fine mica, though flesh-colored feldspar is regarded as exerting an injurious influence, as also the preponderance of quartz, and the presence of uranium minerals. These assertions must, however, be accepted with caution.

### ASSOCIATED MINERALS.

The minerals found in mica veins are both numerous and interesting. Some time before his death in 1885 the lamented W. C. Kerr, for twenty years State Geologist of North Carolina, prepared a list of the minerals found in mica veins, and this has been corrected by F. A. Genth and one or two added by W. E. Hidden.

The list is as follows, according to Kerr:

| | | | |
|---|---|---|---|
| Albite, | Biotite, | Limonite, | Thulite, |
| Allanite, | Columbite, | Magnetite, | Torbernite, |
| Amazon stone, | Euxenite, | Menaccanite, | Tourmaline, |
| Apatite, | Glassy feldspar, | Muscovite, | Uraninite, |
| Arethunite, | Garnet, | Phosphuranylite, | Uranocher, |
| Autunite, | Gummite, | Rogersite, | Uranotil, |
| Beryl. | Hatchettolite, | Samarskite, | Yttrogummite. |

F. A. Genth* corrects this list, and his criticisms are as follows:

"Amazon stone, perhaps, doubtful.

"Autunite (torbernite?), *all* autunite.

"Biotite, probably, but I have not seen it from mica veins, as far as I remember.

"Euxenite, does not contain $TiO_2$, and hence is not true euxenite.

"Glassy feldspar (sanidin), very doubtful.

"Pyrochlore, in very minute octahedra at the Ray mine, with black tourmaline.

"Yttrogummite—I do not know of any analysis having been made; very doubtful.

"Fluorite, in pseudomorphous granular patches after apatite.

"Apatite, seems to be fluorapatite.

"Orthoclase, often completely altered to kaolinite.

"Quartz, of course."

Neither Dr. Genth nor myself are able to identify Kerr's arethunite; it is most likely a *lapsus pennæ*. To this list Hidden has added fergusonite, which now sells for $5 a pound, monazite and æschynite(?). Large masses of samarskite are found in some of the mines, a piece weighing 94 pounds being taken from the Mart Wiseman mine, in Mitchell county.† This formerly sold, I believe, for $1.50 per pound, but is now offered at 75 cents per pound. The largest piece ever found have been obtained from Mitchell county.

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*Priv. com., October 3d, 1887.

†D. A. Bowman, priv. com., November 5th, 1887.

A rather curious bit of history and of etymology is associated with the feldspar altered to kaolinite. W. C. Kerr, in the paper previously referred to, says that the Indian name for the Smoky Mountains, *Unaka* mountains, is derived from the Indian word for *white*, Unakeh, and that they applied this name to them because they were accustomed to obtain white kaolin there, and to "pack" it to the coast for exportation 150 years ago. He does not give his authority for this statement, and I have not been able to find it. He may have ascertained it himself, but if so, he makes no mention of it.

The farmers near the mines are accustomed to apply the disintegrated feldspar to their crops, and it has given good results, containing as it does from 10 to 15 per cent. potash. Some attempts have been made to utilize the feldspar as a source of potash, but the experiment has not been successful on a commercial scale. With kainit of 13 per cent. potash, selling at $11 per ton, it is doubtful whether the potash can be economically extracted from feldspar. I am informed that interest in the problem has somewhat revived of late. The material can be had in any quantities at an almost nominal cost, as it is obtained in great abundance, and constitutes at least one-third of the dumps.

From the list of minerals found in mica veins it will be seen that many of them are rare, and some quite so. Whatever agencies were at work during the formation of these veins they seem to have conditioned the occurrence of some of the rarer minerals in considerable quantities. It is not without interest that fluorine was present at the time, occurring as it does in fluorite and fluorapatites. The well-known decomposing power of this element, when present as hydrofluoric acid, or combined with lime, may have a bearing upon the constitution of the mica vein itself and of the minerals found in it. I have examined numerous specimens of apatite from Mitchell county, and so far have not observed any chlorapatite. Dr. Genth's experience, stretching over a much longer time than my own, and based on many more examinations, would seem to be in the same direc-

tion. The apatite is generally of the greenish variety, is well crystallized, and is usually imbedded in the feldspar. It does not occur in sufficient quantity to be of much value, although the fine crystals can of course be sold to mineral dealers, and occasionally an extra fine crystal may be used as a gem stone. Some large, and a few really handsome, beryls have been found, notably at the Ray mine, in Yancey county. An hexagonal crystal, now in the possession of the writer, but unfortunately broken, is $8\frac{1}{2}$ inches long, and was originally $3\frac{1}{2}$ inches in diameter. It is, however, quite opaque.

At the Grassy Creek mine, Mitchell county, crystals 2 feet long and 7 inches in diameter have been found.†

The recent discovery of germanium in euxenite* lends some interest to the reported discovery of this mineral in mica veins. Dr. Genth, however, says that the mineral reported as euxenite does not contain $TiO_2$, and is hence not a true euxenite, and as germanium, besides occurring in argyrodite, is supposed to accompany titanium, it is hardly likely to be present in the so-called euxenite. Allanite is found in slender, black crystals, 6–12 inches long, at the Balsam Gap mine, Buncombe county, and at the Clarissa (Buchanan) mine, Mitchell county.

Albite occurs at the Presly mine, Haywood county, as an alteration product of the decomposition of the corundum.† Columbite occurs imbedded in samarskite at the Wiseman mine, Mitchell county, and rogersite at the same mine "in white mamillary crusts and little pearly beads upon samarskite."

Monazite occurs in feldspar at the Ray mine, autunite and phosphuranylite on quartz and feldspar at the Flat Rock and Clarissa mines, Mitchell county.

A piece of gummite weighing 6 pounds 6 ounces, but partly altered to uraninite, has been found in Mitchell county according to W. E. Hidden.

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*Minerals and mineral localities of North Carolina. 1881. F. A. Genth and W. C. Kerr.

†See abstract of Gerhard Krüss's paper before Munich Chem Soc., Dec. 16, 1887, in Engineering and Mining Journal, Vol. XLV, No. 7, p. 125.

## DRESSING THE ROUGH MICA.

The rough mica is hoisted from the mine in blocks of considerable size, weighing from 50 to 250 pounds, tabular in shape, and more or less contaminated with fragments of feldspar, quartz, waste mica, etc. It is the purpose of the dressing to free the blocks from all materials not made use of in preparing cut mica. This is all done by hand, and consists in cleaving a block with thin steel wedges along the planes of lamination, separating it into a number of tabular pieces about $\frac{1}{2}$ inch thick, and as large as the stock will allow. These pieces are then further cleaved until the proper thickness for cut mica is attained, this being, according to the use it is to be put to, from $\frac{1}{8}$ to $\frac{1}{16}$ inch, or even thinner. The workman doing this also frees the sheets from adhering quartz, fragments of mica, etc., and passes them to the "scriber."

Scribing is an operation demanding a considerable degree of skill and experience. Upon it depends the yield of cut from block mica. It is performed by laying upon the sheet the pattern by which it is to be cut, and marking or scribing around it with a knife or similar instrument. The patterns are pieces of tin, sheet-iron, etc., with the shape and size determined by the order from the mica brokers or dealers in the large cities, or by the stove maker himself. In Mitchell county alone there are about 100 different patterns, and their shape and size is constantly varying according to the fashion of the stove windows. The size of cut mica was formerly of much greater consequence than at present. Several years ago there was a regular and systematic increase in value with the increase in size, the quality of course remaining the same. This is true to some extent now, though there appears to be a decided tendency towards smaller patterns. The first noticeable change in this respect was perhaps in 1883–'84, when the stove manufacturers were compelled by the scarcity of large mica to use smaller sheets. They found the change so advantageous to their pockets that they persevered in it, and thus influenced the mica trade no little.

I would not be understood as saying that small mica is as valuable as large mica, but that large sheets are not as valuable as they were ten years ago. There is a limit beyond which it is not safe to go, and I should be inclined to put it at 3 × 6 inches. The patterns range in size from 1 × 1 inch up to 8 × 10, or as large as the stock will permit, increasing one-fourth inch each time. As the value of the mica increases at the same time it becomes necessary to cut from a given rough sheet the largest number of patterns of the highest market value. The price of mica depends not only upon the size but also upon its freedom from specks, stains, cloudiness and striations, these conditioning its quality. Of late, too, a certain amber or rum colored mica has become fashionable, and fancy prices are sometimes paid for a good lot of extra "rum" mica. The regular colorless or "white" mica, however, commands the bulk of the trade. Certain mines, as, for instance, the Clarissa, are famous for "rum" mica.

As, after the scribing, the sheets are cut with heavy shears along the lines marked down it will at once appear that much skill and experience are required of a good scriber. He must be constantly on the alert to furnish from every piece the largest number of valuable cut sheets. With the diversity in patterns and prices, and the variation in the mica itself, this becomes no easy task. A good scriber always commands good wages, for upon his skill depends the yield of cut from block mica. No matter how much block mica is brought to bank, nor how good the quality of it, if the sheet be not properly scribed the yield of cut mica diminishes, and with it the profit. A really skillful scriber will get from a given block twice as much cut mica as a beginner. He sees at a glance just what patterns a certain sheet should yield, he instantly detects flaws, stains, etc., and with a few rapid movements of his marking implement he "scribes" the sheet and passes it to the "cutter," who merely cuts the sheet through along the lines marked. The different sizes are then cleaned of the fine filaments of mica with a stiff brush, wrapped in strong paper, generally in one pound packages, boxed

and shipped. As most of the mines lie from 20 to 30 miles from rail, the haulage across country is costly. A railroad now being surveyed down the Toe River, between Mitchell and Yancey counties, will give an outlet north *via* the East Tennessee, Virginia & Georgia Railroad, and south *via* the Richmond & Danville (Western North Carolina Division), or the Charleston, Cincinnati & Chicago Railroad, now building. I approach the subject of the yield of cut mica from block mica with some hesitation. Cut mica is the only product of a mica mine that is sold on a commercial scale. It determines the value of the mine. So much depends on the quality of the blocks and of the rough sheets, whether they are stained, or cloudy, or flawey, or striated, so much depends on the skill of the scriber, and other local conditions that what is here said is to be taken as applicable to average conditions.

On the average, therefore, 100 pounds of block mica should yield from 10 pounds to 12 pounds of cut mica. Instances are not unknown where the yield has fallen to 5 per cent.; it has risen at some mines to 33 per cent., and once to 75 per cent. This last yield is very far above the average, and has been obtained only once, so far as I know. With the general average of block mica a 12 per cent. yield in cut mica is considered a fair return. These 12 pounds will vary in value according to the quality and size of the patterns, the highest price being $4 per pound, the average price being not far from $1.75.

A 12 per cent. yield with these figures will give an average value of $21 per 100 pounds of block mica, or $420 per ton of 2,000 pounds. That the business has been profitable may be realized by remembering as stated already in this article, that in 1880 there was invested in North Carolina mica mines $6,900, and the value of their product was $61,675. As was remarked then, I cannot say whether these figures are correct or not. One may be allowed one's own opinion, and some would say it is too good to be true. It has been stated that in the Carolinas the mica is more apt to have a twisted structure and to be stained or cloudy than the New Hampshire mica. This could be known

only by comparing the percentage yield of cut mica from block mica, as twisted or A mica and stained mica is not included in cut mica.

Prof. Shaler speaks also of the relatively small amount of gangue in the richer parts of the vein compensating for the increased expense of mining Carolina mica. This has less to do with the yield of cut mica than the quality of the blocks. The greater or less preponderance of gangue may, and doubtless does, influence the mining account, and so, indirectly, the balance sheet; but the value of 100 pounds of block mica depends less upon the percentage of gangue than upon the quality of the cut mica obtained from it. The assertion that Carolina rough mica yields less cut mica than that from New Hampshire remains to be proved.

## CONCLUSION.

In bringing this article to a close it seems necessary to explain why no statistics have been given. Such as are accessible will be found in a compilation by the writer to be published shortly in the "Mineral Resources of the United States for 1887," U. S. Geol. Survey. In this volume will be found also a more concise and less technical account of the industry, and those who wish a bird's-eye view of the matter are referred to it.

North Carolina, for several years past, has contributed over 60 per cent. of the mica produced in the United States. With New Hampshire, she produces fully 95 per cent. of the better quality of mica in the country, and while, indeed, it cannot be asserted that her mica is better than that from other sources, it is just as good, and the statistics above referred to show that it is mined at less cost than New Hampshire mica.

I must say, however, that in my opinion these statistics are erroneous. There cannot exist such a difference between the effective value of a dollar in North Carolina and New Hampshire as they reveal. It is impossible to believe that one dollar in North Carolina yielded $8.93, and in New Hampshire only 20 cents, especially when we consider that in the former State

shaft mining is the rule and open cut the exception, and in the latter open cut is the rule and shaft mining the exception.

The much vexed question of cost accounts should not be submitted to census-takers. It needs something more than mere scientific information to settle the actual cost of even so simple a product as mica, and while the local conditions in North Carolina favor cheap mining they do not necessarily imply it. After devoting several years to the study of North Carolina mica mines, and, what is a still more difficult subject, mica *miners*, I do not as yet find myself in a position to give an opinion on the cost of a pound of mica ready for shipment. That it is less now than it was ten years ago there is good reason for believing, as also for believing that it will be still farther diminished by the introduction of improved machinery, drills, hoists, etc.

The miners and dealers in North Carolina are not at present at all happy over their prospects. The change to a smaller pattern, the importation of foreign mica (which pays no duty), and the discovery of other mines, as in Dakota, Black Hills, Colorado, etc., are among the chief causes of alarm.

The output is diminishing, and that in spite of many good mines still unworked. The industry, while, indeed, never of any very great dimensions, was of considerable consequence to the immediate vicinity.

Probably $300,000 was the geatest value ever reached by any annual yield, and for the 20 years in which the business has been carried on it is not likely that the value of the product exceeds $1,700,000.

Mitchell and Yancey counties have contributed most of the mica from North Carolina. Good mines have also been opened and worked in the counties of Stokes, Cleveland and Rutherford, east of the Blue Ridge, and Buncombe, Haywood, Jackson, Macon and Cherokee, west of the Ridge.

According to W. C. Kerr, a timbered shaft 100 feet deep has been discovered on Valley River, Cherokee county.

F. W. Simonds* states that in the Guyer mine, Macon county,

*American Naturalist, 1881, 7.

at depths varying from 35 to 50 feet in a shaft of prehistoric age, were found in 1875 some iron implements, as a pair of gudgeons, a wedge, etc., of wrought-iron. Shaft mining has been carried on in this State for 200 years or more. An exploring party sent out by De Soto may have penetrated as far north as the south-western corner of North Carolina.

Prehistoric remains of open cuts and shafts for mica mining are found in Alabama, along a line stretching from Chilton county north-east through the counties of Coosa, Clay and Cleburne.

It is a little surprising that an industry so old, and yet so new, should have received such scant attention. There is, perhaps, in the whole country no better place for the study of fissures, and of the forces causing them, than a well opened mica mine.

It is the purpose of the writer during the ensuing summer to figure and describe more particularly some of the more interesting of these mines in Yancey and Mitchell counties, and to seek anew for the relations subsisting between the quality and quantity of the mica, and the depth, dip, strike and walling of the vein, and the influence exerted by accompanying minerals.

If what has been said shall lead those concerned in such matters to inquire more especially into them, this article has not been written in vain. The mica mining counties will well repay close study, not only on account of the mica, but even more on account of other minerals, as iron ores, chrome ores, corundum, asbestos, graphite, talc, etc. Some of the most magnificent forests of virgin timber in this or any other country still adorn the mountains and hills of these counties. Chestnut, locust, walnut, poplar, pine, cherry, etc., flourish in great abundance and beauty. The new railroad projected down the Toe river in Tennessee will open a country that needs only to be known to be appreciated. A fertile soil, an unsurpassed climate, varied and abundant natural products all combine to render this part of North Carolina the potential garden spot of the State.

# RECALCULATIONS OF THE ATOMIC WEIGHTS.

F. P. VENABLE.

Within the last five years several attempts have been made by chemists of prominence to recalculate the many atomic weight determinations upon a uniform basis and by uniform methods, and so secure, if possible, a trustworthy table of these most important constants of nature. Our better knowledge of these elements and the increased accuracy of modern methods promised favorably for the success of such an undertaking. That such a revision was called for a glance at the text-books of the time will abundantly show. The greatest variance was shown in the tables of atomic weights given. They seemed to be chosen most arbitrarily. No single authority was recognized, and in many cases it would have been difficult to trace the source of the numbers given. Especially were the differences notable in text-books of different nationalities. Taking two nearly contemporaneous text-books widely used in England, America and Germany—Watts (1878) and Richter (1881)—I find that out of 64 elements 37 per cent. only have the atomic weights the same in both; 22 per cent. differ by from .10 to .25; 20 per cent. differ from .25 to .50; 10 per cent. differ from .50 to 1.00, and 11 per cent. differ by more than 1, the difference in several cases ranging from 25 to 40.

To call such a list a table of constants seems ridiculous, nor does it speak well for chemistry as a science that these, the very foundation stones on which its building is reared, should be so unstable and little trustworthy. Analyses calculated by numbers so different, as in these two tables, must give very different results, one or the other, or perhaps both, of which must be erroneous.

The evil was and is a crying one and demands the best energies of the wisest chemists to rectify.

The general acceptation of the Law of Periodicity has been another potent factor in drawing attention to the need for careful revision, and in many cases re-determination of the atomic weights. Those who have undertaken this revision have met with many serious obstacles which are still very far from being overcome. This, I think, will be seen as we proceed in the discussion of the results obtained.

## THE UNIT OR BASIS.

The first essential is the adoption of a unit of calculation or basis, and this has proved one of the great obstacles in the way of uniformity. Two elements suggest themselves as bases for these calculations—hydrogen and oxygen. For fifty years or more the strife has raged as to which of these should be adopted. Hydrogen has been practically adopted and used, but the opposition to it has only slumbered at times and seems rising again in the past few years. Dalton and Gmelin were the advocates of the hydrogen unit in early days and Wollaston and Berzelius advocated oxygen. Among the late revisers and recalculators Becker* refers all the atomic weights to oxygen=16. Clarke† gives tables calculated either for oxygen=16 or hydrogen=1. Sebelien‡ uses the units, hydrogen=1 or oxygen=100, as also do Meyer and Seubert§. Ostwald¶ uses hydrogen=1, giving to oxygen the value 16. Van der Plaats‖ has selected oxygen=16 as the basis for his recalculation.

There is a decided predominance of authority in favor of oxygen as the standard and of giving it the value 16, though some would make it appear that this is the same thing as adopting hydrogen=1.

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*Constants of Nature, Part IV, Smithsonian Institution, 1880.

†Constants of Nature, Part V, Smithsonian Institution, 1887.

‡Beiträge zur Geschichte der Atomgewichte, 1884.

§Die Atomgewichte der Elemente, 1883.

¶Lehrbuch der Allgemeinen Chemie, 1885.

‖ Annales de Chimie et de Physique (6 serie) 7 April, 1886.

What points should decide the choice of our unit? They have been ably discussed by Meyer and Seubert,* but I must confess they seem to me somewhat blinded themselves by the partisanship of which they accuse their opponents, and I cannot agree with them in all of their conclusions.

I would state as the essentials for the unit element:

1st. That it must be one with which the greatest number of the other elements can be directly compared, thus avoiding the multiplication of error.

2d. Its own atomic weight must be reasonably small so as not to make too great the higher atomic weights.

3d. The atomic weights of the other elements gotten by comparison with it should be, as many of them as possible, integers, or nearly so, rendering calculation easier. In spite of all the tabular and other aids at the command of the chemist of the present day, calculations with an atomic weight having an awkward fraction cause the loss of much time.

Now, on examining, with a view to these requisites, the two elements proposed as units oxygen alone will be found to answer every requirement.

Nearly all of the present atomic weights have been determined by the aid of oxygen.

Few can be directly compared with hydrogen, and this forms the almost insuperable objection to hydrogen as a standard.

Hydrogen has been used for the past half century for the two last reasons cited among the requisites. As it has the smallest atomic weight, all the others would be above unity if it were taken as the unit. Thus fractional atomic weights were avoided, and again a large number of the other atomic weights compared with it are approximately integers. I am confident that this is mainly made use of as a matter of convenience and of custom at the present day, and that no special weight is attached to the coincidences with whole numbers. It did give rise to a visionary sort of hypothesis, first enunciated by the Rev. Mr. Prout in 1815, and hence

*Berichte der deutschen Chem. Gesell., XVIII, 1,089.

called Prout's Hypothesis, that all of the atomic weights were multiples of that of hydrogen, and, as an inference to be drawn, that hydrogen was the primal element of which they were made.

This hypothesis has had many valiant defenders and a large number of most determined opponents, and it has called forth work that has been of immense benefit to the science. It is well that this one good thing can be spoken of so many false suppositions and theories. As an hypothesis it is based on a few coincidences which were to be naturally looked for in the light of mathematics and the law of probabilities. One may say that no absolute proof in its favor has ever been advanced, nor does it seem capable of proof at the present day. A cursory examination would reveal proportionately similar coincidences for some of the other elements. I say proportionately for, of course, the smaller the atomic weight the greater the number of its multiples and the greater the probability of coincidences within the limits given.

I cannot believe that Meyer and Seubert* are serious when they state it as a "striking fact that the atomic weights of more than one-fourth of all the elements are very nearly multiples of the half atomic, or equivalent weight of oxygen," giving a table to show this, and adding that "such regularities are worthy of note." They can scarcely be worthy of much note, for such regularities or coincidences would be exceedingly probable where we have sixty or seventy elements with atomic weights under 240 and take a small number with thirty or more multiples in the same range. The smaller the number the more numerous will be the multiples and consequently the coincidences. To show this, I have added to the table of Meyer and Seubert two other lists of multiples and "regularities."

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*Loc. cit.

**TABLE No. 1.**

| Factor. | Multiples of 7.98=½ O. | Elements. | Differences. | Multiples of 3.52=⅓ Li. | Elements. | Differences. | Multiples of 6=½ C. | Elements. | Differences. |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 15.96 | O | 0 | 7.04 | Li | 0 | 12.00 | C | 0 |
| 3 | 23.94 | Mg | 0 | 10.56 | Be | +.44 | 18.00 | | |
| 4 | 31.92 | S | +.06 | 14.08 | Ni | −.04 | 24.00 | Mg | +.38 |
| 5 | 39.90 | Ca | +.01 | 17.60 | | | 30.00 | | |
| 6 | 47.88 | Ti | +.13 | 21.12 | | | 36.00 | Cl | −.55 |
| 7 | 55.86 | Fe | +.02 | 24.64 | Mg | −.26 | 42.00 | | |
| 8 | 63.84 | Cu | −.66 | 28.16 | Si | −.10 | 48.00 | Ti | +.12 |
| 9 | 71.82 | Ge | +.50 | 31.68 | S | +.38 | 54.00 | | |
| 10 | 79.80 | Br | −.04 | 35.20 | Cl | +.25 | 60.00 | Co | −.90 |
| 11 | 87.78 | Sr | −.48 | 38.72 | K | +.41 | 66.00 | Zn | −.62 |
| 12 | 95.76 | Mo | +.14 | 42.24 | | | 72.00 | Ger | +.32 |
| 13 | 103.74 | Ru | −.24 | 45.76 | | | 78.00 | | |
| 14 | 111.72 | Cd | 0 | 49.28 | | | 84.00 | | |
| 15 | 119.70 | Sb | −.10 | 52.80 | Cr | −.50 | 90.00 | Zr | +.70 |
| 16 | 127.68 | | | 56.32 | Fe | −.32 | 96.00 | Mo | −.10 |
| 17 | 135.66 | | | 59.82 | Co | +.28 | 102.00 | | |
| 18 | 143.64 | | | 63.36 | Cu | −.03 | 108.00 | Ag | +.06 |
| 19 | 151.62 | | | 66.88 | | | 114.00 | Ir | −.30 |
| 20 | 159.60 | | | 70.40 | Ga | −.50 | 120.00 | Sb | +.29 |
| 21 | 167.58 | | | 73.92 | | | 126.00 | Te | −.80 |
| 22 | 175.56 | | | 77.44 | | | 132.00 | Cs | +.88 |
| 23 | 183.54 | W | +.06 | 80.96 | | | 138.00 | La | +.50 |
| 24 | 191.52 | | | 84.48 | | | 144.00 | | |
| 25 | 199.50 | Hg | +.30 | 88.00 | Sr | −.48 | 150.00 | Sm | +.20 |
| 26 | 207.48 | Bi | −.18 | 91.52 | Zr | −.92 | 156.00 | | |
| 27 | 215.46 | | | 95.04 | Mo | +.86 | 162 00 | | |
| 28 | 223.44 | | | 98.56 | | | 168.00 | | |
| 29 | 231.42 | Th | +.54 | 102.08 | | | 174.00 | Yb | −.80 |
| 30 | 239.40 | U | +.40 | 105.60 | Pd | −.60 | 180.00 | | |
| 31 | | | | 109.12 | | | 186.00 | | |
| 32 | | | | 112.64 | Cd | −.56 | 192.00 | | |
| 33 | | | | 116.16 | | | 198.00 | | |
| 34 | | | | 119.68 | Sb | +.61 | 204.00 | Tl | +.15 |
| 35 | | | | 123.20 | | | 210.00 | | |

**TABLE No. 1—Continued.**

| Factor. | Multiples of 7.98—1/8 O. | Elements. | Differences. | Multiples of 3.02—1/8 Li. | Elements. | Differences. | Multiples of 6—1/8 C. | Elements. | Differences. |
|---|---|---|---|---|---|---|---|---|---|
| 36 | | | | 126.72 | I | +.14 | 216.00 | | |
| 37 | | | | 129.24 | | | 222.00 | | |
| 38 | | | | 132.76 | Cs | +.12 | 228.00 | | |
| 39 | | | | 136.28 | Ba | +.76 | 234.00 | Th | —1.00 |
| 40 | | | | 140.80 | Ce | +.70 | 240.00 | U | —1.00 |
| 41 | | | | 144.32 | Di | +.68 | | | |
| 49 | | | | 172.48 | Yb | +.72 | | | |
| 52 | | | | 183.14 | Ta | —.34 | | | |
| 55 | | | | 193.70 | Ir | —.59 | | | |
| 56 | | | | 197.22 | Au | —.48 | | | |
| 57 | | | | 209.74 | Hg | —.30 | | | |
| 58 | | | | 204.26 | Tl | —.11 | | | |
| 59 | | | | 207.78 | Bi | +.23 | | | |
| 62 | | | | 218.34 | Ng | +.66 | | | |
| 68 | | | | 239.46 | U | +.54 | | | |

I cannot think that these authors really mean this as in any way a plea for oxygen=15.96. It must be intended to show the ridiculous nature of the grounds upon which Prout's Hypothesis has been based. Certainly they are correct in their deduction that "to attempt to correct the atomic weights by them (*i. e.*, these regularities) would be just as incorrect as to round them off into whole numbers." With such glaring and persistent exceptions as chlorine, chromium, copper, strontium, gold and others, the hypothesis of Prout must fail to take its place as a law, since no law could be accepted with so large a percentage of exceptions.

It is not necessary to discuss the modifications of Prout's Hypothesis which have been proposed—the half-atom or fourth-atom of hydrogen as unit, etc. Such changes really do away with all meaning to the hypothesis, and the valuable idea which Meyer and Seubert acknowledge may lie concealed in it, is lost.

That the hypothesis is still doing yeoman's service to science is shown by the number of new determinations, within the past two years, of the ratio between hydrogen and oxygen. It is

evidence of the struggle to retain the old unit hydrogen, and at the same time secure accuracy for it, by fixing definitely its relation to oxygen, by means of which nearly all comparisons with the other elements must be made. I fear that much of this work would not have been done if it had been made to appear that the atomic weight of hydrogen, and not of oxygen, was aimed at. The atomic weight of hydrogen has only the ordinary interest of that of any of the elements. With the atomic weight of oxygen they all stand or fall, no matter which we choose as our theoretical unit. The new determinations referred to are:

Rayleigh (Chemical News, Vol. 57, p. 73), O=15.912.

Cooke & Richards (Am. Chem. Journal, Vol. 10, p. 81), O=15.953.

Cooke & Richards (Am. Chem. Journal, Vol. 10, p. 91), O=15.869.

Keiser (Am. Chem. Journal, Vol. 10, p. 250), O=15.949.

Morley,* is at work upon it and cites Scott, H:O :: 1.994:1, by volume. This makes the atomic weight of oxygen less that 16, as all of the others do. None of them come up, indeed, to the present assumption of O=15.96, so if these investigators are correct, or more nearly correct than those who have preceded them, the whole table of atomic weights must be again shifted.

It is time, then, that hydrogen were finally discarded as the unit. Oxygen is in every way preferable, and nothing like uniformity will be attained until it is adopted.

With oxygen as the standard, what value shall be assigned it? Four values have been suggested: 1st, O=1; 2d, O=10; 3d, O=16; 4th, O=100.

If O=1 we would have nearly 10 per cent. of the elements represented by decimal fractions and the following partial table would show other inconveniences:

| | | | |
|---|---|---|---|
| Al. | 1.694 | Cr | 3.284 |
| F | 1.194 | Fe | 3.501 |
| Mg | 1.500 | Co | 3.67 |
| Na | 1.4408 | Cu | 3.95 |
| P | 1.940 | Mn | 3.43 |
| S | 2.0037 | Ni | 3.67 |
| | | Ti | 3.15 |
| Si | 1.754 | V | 3.20 |

*American Chemical Journal, Vol. 10, p. 21.

The differences between the elements are too small for speedy recognition or for easy memorizing. O=1 is manifestly too small.

Considering next the fourth suggestion, O=100, we see that just the opposite objection holds good. Over one-fifth of the elements would be represented by numbers exceeding 1000. Few of these could be accurately given as far as the fourth place. For instance, shall gold be represented by the number 1229.4, or 1225.1, or 1234., or 1249., all of which are actual determinations? From long custom we have come to regard a whole number as being correct and the decimals as indicating approximations. It would seem to be best still to hide our imperfections under the decimals.

The only claim that can be adduced in favor of O=10 is that we will then have the atomic weights on the decimal system. This is not true, however, unless the other atomic weights are multiples of ten. A glance at a few of the elements will show that the numbers would be complicated, rather than simplified, by such an unit.

| | |
|---|---|
| H — 6.265 | C — 7.502 |
| Li — 4.39 | N — 8.779 |
| Be — 5.89 | F —11.94 |
| B — 6.83 | Na —14.408 |
| C — 7.502 | Fe —35.01 |
| N — 8.779 | Co —36.70 |
| F —11.94 | Mn—34.30 |
| Na—14.408 | Cu —39.50 |

That is, the eight first elements which in our present tables are approximately whole numbers and in ordinary calculations commonly taken as such (especially in technical analyses, and we must not let theoretical considerations take us out of sight of the practical side of chemistry) are when compared with O=10 burdened with cumbrous fractions and brought inconveniently near to one another. This last consideration is of especial weight when the clearness of the Periodic Law is considered.

There remains, then, only O=16 to be considered. The advantage of this unit may be summed up as follows:

1st. Every atomic weight is above unity and yet not inconveniently large.

2d. The distance between the atomic weights renders them easy to memorize and is more convenient for the illustration of the Periodic Law.

3d. About two-thirds of the atomic weights are either whole numbers or vary from whole numbers by fractions of $\frac{1}{10}$ or less.

4th. The adoption of this as a unit practically means the retention of most of the numbers so long in use. The valuable literature of the past three or four decades need not be rendered less useful and intelligible to the chemists of the present and the future, as it would be by radical changes in these combining numbers.

Some chemists seem to feel an especial repugnance to this unit because it is too arbitrary and unusual, not bearing upon its face the fact that it is the unit, and again because hydrogen is then represented by the number 1.0025. The arbitrariness of it seems unavoidable: as to why they should be troubled by the number given hydrogen is not very apparent. The fraction is an easy one to handle and may often be neglected. It can make no possible difference in the close calculations of organic chemistry cited by Meyer and Seubert, whether H=1 and O=15.96 or H=1.0025 and O=16. The only thing is to keep the ratio which most exact research reveals as existing between the two. The tendency of the day is toward O=16 and it should be universally adopted. To avoid dangerous assumptions the other atomic weights should be rigidly put down in accord with the most accurate determinations available. This brings us to consider another difficulty and cause of variation.

## METHODS OF CALCULATION.

Clarke, Sebelien, and others, who have worked over this problem, have been greatly troubled as to what data should be used in the recalculations and what rejected. Manifestly the results of many of the older experimenters can lay no great claims to accuracy. Some, as Clarke says, are "chemically worthless because of constant errors." Many have neglected proper precautions or necessary corrections. And yet there are

reasons for retaining much of this, and the retention or rejection is a point of judgment on which chemists may, and do, legitimately differ. An additional sentence of Clarke's reveals the extent of the trouble. "In fact, it is doubtful," he says, "whether any two chemists, working independently, would handle all the data in precisely the same way, or combine them so as to produce exactly the same final results."

The accompanying tables, giving the calculations of Clarke, Meyer and Seubert (the O=16 table was worked out from their O=1), Van der Plaats, and Ostwald,* show the truth of this. The two last agree more nearly than the others, and yet the variations are numerous and sometimes as large as 5 in the case of osmium; 3 in the case of mercury; 1 in the case of uranium, etc. Unanimity in regard to an atomic weight does not always mean that the weight is correct. Paucity of data sometimes limits the chances for variation. Indium, for instance, and gallium and beryllium have been subjected to few investigations.

The mathematical side of the question, whether the method of least squares should be adopted, or by what formulæ the probable errors should be calculated, and by what the results combined, is, of course, of great importance, and the subject of varying views, but cannot be discussed here.

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*Ostwald's table is put down under the head of O=16. He gives it as H=1 and also O=16, but the numbers most nearly correspond with the latter.

**TABLE No. II.**

| OXYGEN=16. | | | | | HYDROGEN=1. | | |
|---|---|---|---|---|---|---|---|
| Symbol. | Clarke. | Meyer & Seubert. | Van der Plaats. | Ostwald. | Symbol. | Clarke. | Meyer & Seubert. |
| Ag | 107.923 | 107.929 | 107.93 | 107.938 | Ag | 107.675 | 107.66 |
| Al | 27.075 | 27.107 | 27.08 | 27.08 | Al | 27.009 | 27.04 |
| As | 75.090 | 75.087 | 75.0 | 75.0 | As | 74.918 | 74.9 |
| Au | 196.606 | 196.690 | 196.7 | 196.7 | Au | 196.155 | 196.2 |
| B | 10.966 | 10.927 | 11.0 | 11.0 | B | 10.941 | 10.9 |
| Ba | 137.407 | 137.202 | 137.1 | 137.04 | Ba | 136.763 | 136.86 |
| Be | 9.106 | 9.103 | 9.1 | 9.10 | Be | 9.085 | 9.08 |
| Bi | 208.001 | 208.019 | 208.0 | 208.01 | Bi | 207.523 | 207.5 |
| Br | 79.951 | 79.954 | 79.955 | 79.963 | Br | 79.768 | 79.76 |
| C | 12.0011 | 11.999 | 12.005 | 12.000 | C | 11.9736 | 11.97 |
| Ca | 40.082 | 40.09 | 40.0 | 40.00 | Ca | 39.990 | 39.91 |
| Cd | 112.092 | 111.979 | 112.1 | 112.08 | Cd | 111.835 | 111.7 |
| Ce | 140.747 | 141.553 | 141.5 | 141.5 | Ce | 140.424 | 141.2 |
| Cl | 35.451 | 35.458 | 35.456 | 35.453 | Cl | 35.370 | 35.37 |
| Co | 59.023 | 58.746 | 58.8 or 60 | 59.1 | Co | 58.887 | 58.6 |
| Cr | 52.127 | 52.581 | 52.3 | 52.3 | Cr | 52.009 | 52.45 |
| Cs | 132.918 | 133.032 | 132.8 | 132.88 | Cs | 132.583 | 132.7 |
| Cu | 63.318 | 63.338 | 63.33 | 63.33 | Cu | 63.173 | 63.18 |
| Di | 144.906 | 145.362 | 145 | 145 | Di | 144.573 | 145.0 |
| Er | 166.273 | 166.415 | 166 | 166 | Er | 165.891 | 166. |
| F | 19.027 | 19.109 | 19.0 | 19.01 | F | 18.984 | 19.06 |
| Fe | 56.042 | 56.015 | 56.0 | 56.00 | Fe | 55.913 | 55.88 |
| Ga | 68.963 | 70.072 | 70. | 69.9 | Ga | 68.854 | 69.9 |
| Ge | 72.32 | —Determination of | | Winkler. | Ge | | |
| H | 1.0023 | 1.0024 | 1.00 | 1.00 | H | 1.0000 | 1.00 |
| Hg | 200.171 | 200.299 | 200.1 | 200.4 | Hg | 199.712 | 199.8 |
| I | 126.848 | 126.856 | 126.86 | 126.864 | I | 113.398 | 113.4 |
| In | 113.659 | 113.683 | 113.7 | 113.7 | In | 113.398 | 113.4 |
| Ir | 193.094 | 192.981 | 193.0 | 193.11 | Ir | 192.651 | 192.5 |
| K | 39.109 | 39.128 | 39.144 | 39.136 | K | 39.019 | 39.03 |
| La | 138.844 | 138.846 | 138.0 | 138.5 | La | 138.526 | 138.5 |
| Li | 7.0235 | 7.028 | 7.02 | 7.030 | Li | 7.007 | 7.01 |
| Mg | 24.014 | 23.999 | 24.4 | 24.38 | Mg | 23.959 | 23.94 |
| Mn | 54.029 | 54.937 | 55.0 | 55.02 | Mn | 53.906 | 54.8 |
| Mo | 95.747 | 96.139 | 96.0 | 95.9 | Mo | 95.527 | 95.9 |
| N | 14.079 | 14.045 | 14.05 | 14.041 | N | 14.021 | 14.01 |
| Na | 23.051 | 23.052 | 23.05 | 23.058 | Na | 22.998 | 22.995 |
| Nb | 94.027 | 93.934 | 9.40 | 94.2 | Nb | 93.812 | 93.7 |
| Ni | 58.062 | 58.746 | 58. or 58.8 | 58.5 | Ni | 57.928 | 58.6 |
| O | 16.000 | 16.000 | 16.000 | 16.00 | O | 15.963 | 15.96 |
| Os | 198.951 | 195.487 | 195 | 200 | Os | 198.494 | 195. |
| P | 31.029 | 31.037 | 30.95 | 31.03 | P | 30.958 | 30.96 |
| Pb | 206.946 | 206.906 | 206.91 | 206.911 | Pb | 206.471 | 206.39 |
| Pd | 105.981 | 106.465 | 106.5 | 106. | Pd | 105.737 | 106.2 |
| Pt | 194.867 | 194.826 | 194.9 | 194.83 | Pt | 194.415 | 194.34 |
| Rb | 85.529 | 85.413 | 85.4 | 85.44 | Rb | 85.251 | 85.2 |
| Rh | 104.285 | 104.360 | 104. | 103.05 | Rh | 104.055 | 104.1 |
| Ru | 104.457 | 103.759 | 104. | 103.8 | Ru | 104.217 | 103.5 |
| S | 32.058 | 32.059 | 32.06 | 32.063 | S | 31.984 | 31.98 |
| Sb | 120.231 | 119.899 | 120.0 | 120.29 | Sb | 119.955 | 119.6 |
| Sc | 44.081 | 44.079 | 44. | 44.09 | Sc | 43.980 | 43.97 |
| Se | 78.978 | 79.067 | 79. | 79.07 | Se | 78.797 | 78.87 |
| Si | 28.200 | 28.07 | 28.0 | 28.06 | Si | 28.195 | 28.0 |
| Sm | | | 150 | 150.2 | Sm | | |
| Sn | 117.968 | 117.643 | 118.1 | 118.12 | Sn | 117.698 | 117.35 |
| Sr | 87.575 | 87.518 | 87.5 | 87.52 | Sr | 87.374 | 87.3 |
| Ta | 182.562 | 182.455 | 182.8 | 182.8 | Ta | 182.144 | 182. |
| Te | 128.254 | 128.019 | 125 | 125.2 | Te | 127.960 | 127.7 |
| Th | 233.951 | 232.539 | 233 | 233 | Th | 233.414 | 231.96 |
| Ti | 49.961 | 50.373 | 48.1 | 48.12 | Ti | 49.846 | 50.25 |
| Tl | 204.183 | 204.209 | 204.2 | 204.146 | Tl | 203.715 | 203.7 |
| U | 239.030 | 240.399 | 240 | 239 | U | 238.482 | 239.8 |
| V | 51.373 | 51.228 | 51.3 | 51.21 | V | 51.256 | 51.1 |
| W | 184.032 | 184.059 | 184.0 | 184.0 | W | 183.610 | 183.6 |
| Y | 90.023 | 89.824 | 89.5 | 89.0 | Y | 89.816 | 89.6 |
| Yb | 173.158 | 173.081 | 173 | 173.2 | Yb | 172.761 | 172 |
| Zn | 65.054 | 65.042 | 65.3 | 65.38 | Zn | 64.9045 | 64.88 |
| Zr | 89.573 | 90.626 | 90.5 | 90.7 | Zr | 89.367 | 90.4 |

Out of 66 elements the revisers agree on 29 to the tenth place of decimals, differing in the hundredth place only. In the remaining 37, or 56 per cent., the differences are more or less great.

The increased interest in these re-determinations of atomic weights, giving fresh data for calculation and enabling us to throw off some of the burden of faulty determinations, gives promise of an approximately correct table in the near future.

I cannot close without adverting to the speculations of some authors as to the question whether we are to expect these atomic weights to be fixed quantities. In other words,

## ARE THE ATOMIC WEIGHTS CONSTANT?

This question Stas proposed to himself, before starting upon his classic work on the atomic weights. The conclusion he drew from his experiments was that they were unchangeable. The question has been raised again by Schützenberger and Butlerow.* Butlerow does not doubt the results obtained by Stas, but suggests that under changed conditions or with different bodies the results might have been otherwise.

Of course, if the atomic weights are not constant, the law of constant proportions is without support and must be given up, and this would necessitate a revolution in chemistry as a science.

These authors suppose the range of variation in the weights to be very slight, yet distinctly to be detected by analysis. The theories of both are supported by analytical data, in which the authors seem to place the utmost confidence. If their results are not accurate, the variability of the atomic weights stands unproven. To show the nature of their experiments, Sebelien quotes from Schützenberger's work his synthesis of water. According as this is carried out with copper oxide, at red heat, or by the lowest possible temperature, or with lead chromate, the

*Bull. de la Soc. Chim. de Paris, **39**, 258.

*Bull. de la Soc. Chim. de Paris, **39**, 263.

Cited in Zeitschrift für Anal. Chemie, **22**, 640, and Sebelien, Geschichte der Atomgewichte, 54.

relation between the oxygen and hydrogen varies from 7.89 to 7.98. Or again, the atomic weight of iron, determined from the nitrate, he finds to be 54., whilst that from the oxalate is 56. He found also that carbon dioxide prepared by burning pure carbon at a high temperature contained more oxygen than that prepared, by means of carbon monoxide, from organic bodies.

The generality of chemists will be more apt, I think, to suppose the analytical work of these investigators faulty than to accept their conclusions as to the inconstancy of the atomic weights. Yet the matter is of the utmost importance and should be decided with as great freedom from preconceived notions as possible. It is a question exceedingly difficult to decide and will require great nicety and accuracy of work. Many of the most trusted leaders of work and thought in the science will have to concur in testimony derived from their own experiments before any attempt at altering the science to suit the new facts will be made.

We must not say, because we are mentally satisfied with the present theories and dread the trouble which so radical a change would cause, that the supposition is impossible and need not be considered.

Butlerow offers three possible explanations of his own and Schützenberger's observations:

1. The absolute amount of matter has been increased in that the so-called force or energy has been changed into matter.

2. The absolute amount of matter is unchanged, but its weight is increased by means of a temporary increase in the intensity with which the earth attracts matter.

3. The weight of matter is not increased in either way, but the chemical value is changed. The atomic weight of carbon, for instance, may be temporarily changed from 12 to 11.8 and thus the saturation capacity of carbon raised by about $\frac{1}{60}$. The amount of carbonic acid made from the same amount of carbon would thus be increased and would be richer in oxygen.

The first two suppositions would be subversive of Natural Philosophy generally. The last would simply be subversive of Chemistry as now systematized. As Sebelien says, we must give

up, under the third supposition, our idea of atoms, for an atom is nothing if not a fixed weight of something. Vogel* has also come to the conclusion that the atomic weights vary because those gotten by the use of certain compounds differ throughout from those derived from other compounds. By this assumption he also explains the cases in which analyses result in a sum total of over 100 per cent. It seems much more plausible to explain these variations on the ground of errors of analysis, constant errors of method, impurities of materials, and the many other difficulties and obstacles which a chemist meets in such work, than by the radical assumption of an inconstancy in the very constants on which the science is founded and built up.

At any rate until much more proof is forthcoming the matter must rest in abeyance.

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Contribution from N. C. Agricultural Experiment Station.
No. XVII.

## ON THE CHANGE IN SUPERPHOSPHATES WHEN THEY ARE APPLIED TO THE SOIL.

H. B. BATTLE.

Without discussing at this time the value of the soluble phosphoric acid of superphosphates over the phosphoric acid of other forms, nor of the exact nature of the so-called reverted phosphoric acid, I have attempted in this article to show the change that takes place in superphosphates when they are applied to the soil. How the various forms of phosphoric acid, that soluble in water, that insoluble in water, and that insoluble in the standard ammonium citrate solution, all are affected by this application; in other words, when agriculturally the acid

*Nature, Vol. 41, p. 42.

phosphate is applied to the field the original phosphoric acid compounds of the phosphate no longer remain unaltered, but rapidly assume other forms and enter into new combinations. Nor will any special discussion be entered upon as to the exact chemical compounds which are formed by this change, beyond those which may be classified under the general heads of soluble, insoluble, and reverted phosphates.

That superphosphates, after being applied to the soil, when partly dissolved by rains are not leached from the soil, as is the case with some soluble compounds, such as kainit or ammonia salts, is well known. H. Von Liebig* has shown by analysis of the soil and subsoil at Rothamsted of certain plots of land which had received 350 pounds of superphosphate per acre yearly for a period of 22 years that in the first nine inches of the soil three-fourths of the total amount of the phosphoric acid found were present; in the next nine inches the remainder was found; while below this no appreciable quantity was detected over the natural contents of the soil. It is seen, therefore, that out of a total amount of nearly 40 tons applied to the acre during these years none of the soluble phosphoric acid of the superphosphate had been leached or diffused below a depth of eighteen inches, and nearly all had remained less than a foot below the surface. From the result of this examination it is readily seen that the soil prevents excessive diffusion of the soluble phosphoric acid and precipitates it by the action of some of its component parts, in forming less soluble compounds. The cause of this precipitation is due to the presence of lime,† also to the sesquioxides of iron and alumina,‡ and to some extent silica and silicious matters.§

The precipitation in the case of lime salts is undeniably fast; so much so that Wagner¶ thinks that is so great that no diffusion of any kind can exist. While this may be true of soils

*Journal Royal Agricultural Society, 17, 1881, 281.
†Voelcker, Journ. Roy. Ag. Soc., 16, 1, 153.
‡Millot, Jour. d'Ag. Prat., '74, 1, 166.
§Colson, Bull. de la Soc. Chem., '80, p. 153.
¶Lehrbuch der Duüngerfabrikation, '87, 63.

where the content of carbonate of lime is exceptionally high, still with such soils as those containing only a fraction of a per cent. it is not likely that the action is nearly as great, unless it is due to other causes.

The precipitation does not take place till the acid phosphate is dissolved by the rain or soil moisture, and so comes in more intimate contact with the various soil particles. This explains the fact that the action of superphosphates is more apt to be feeble in dry weather than at any other time. In some instances particles of acid phosphate, after having been in the soil for six weeks of continuous dry weather, have been examined and have been found acid and unchanged.

The following experiments are cited to illustrate the action of various soils on superphosphates. The original calculations are further extended so as to be more comparable one with the other:

I. Voelcker, in 1863,* showed that every soil, without exception, acts at once on the superphosphate as soon as it comes in contact with the moist surface. He experimented with various descriptions of soils, using in each case, however, a very large excess of water. To 12 oz. soil were added 109.24 grains or nearly $\frac{1}{4}$ oz. of superphosphate (containing 40.6 grains soluble phosphate) dissolved in $1\frac{1}{2}$ pints of water; or to 12 oz. of soil nearly $\frac{1}{8}$ oz. soluble phosphate was used; equivalent to 1 part of soluble phosphate to 100 parts of soil. With these amounts he obtained the following results (Table I):

**TABLE I.**

SHOWING ACTION OF SOILS ON SUPERPHOSPHATES—VOELCKER'S RESULTS.

| SOILS. | Containing per cent. Oxide Iron and Alumina. | Containing per cent. Carbonate Lime. | In 24 hours were precipitated of the Dissolved Phosphate (containing 40.6 grains). |
|---|---|---|---|
| 1. Red Loamy | 6.10 | 1.22 | 24.29 grns. |
| 2. Calcareous | 7.54 | 67.50 | 31.40 " |
| 3. Stiff Clay Subsoil | 17.38 | 1.02 | 19.30 " |
| 4. Stiff Clay Surface | 7.85 | 2.08 | 20.70 " |
| 5. Light Sandy | 12.16 | .15 | 21.46 " |

*Cited by H. von Liebig, Roy. Ag. Soc., 19, 1, p. 283.

Prof. Nessler, with loamy soil containing 18 per cent. of carbonate of lime, but with 3.4 times as much superphosphate (or 1 part soluble phosphate with 30 of soil), obtained like results.

We notice from the above table: 1st. That lime causes precipitation more than any other element in the soil, for with the largest content of carbonate of lime we have the greatest precipitation; 2d. Nothing definite can be said in regard to the precipitative power of the oxides of iron and alumina, for in mixture 1, with a per cent. of 6.10, the precipitation is 24.29, while in 3, with a content of iron and alumina nearly three times as great, the precipitation is actually less. The same can be said of mixtures 4 and 5, though in a less degree.

In these experiments, however, a very large excess of water was used. While in the soil merely moistening would be the actual condition, we have here a volume of water about three times that of the soil. It is impossible, therefore, to approximate by these experiments the real action on the phosphate by the soil; we must necessarily have a much smaller quantity of water for the experimental mixing.

II. Wagner, in 1877,* records the following experiments. In these the amount of water is much smaller than the foregoing, and much nearer represents what might actually be said to take place in the soil:

Twenty-five grams bone ash superphosphate, containing exactly 5 grams soluble phosphoric acid, was mixed with 60 grams air dry clay soil, containing 5.11 per cent. carbonate of lime, and 6cc. water. After 24 hours in a closed vessel it lost 2.725 grams phosphoric acid: 100 parts of soil absorbed, therefore, under these conditions, 4.81 grams phosphoric acid. In like manner other results were obtained, which I have recorded in Table II.

*Lehrbuch der Duüngerfabrikation, p. 69.

**TABLE II.**

SHOWING ACTION OF SOILS ON SUPERPHOSPHATES—WAGNER'S RESULTS.

| | Superphosphate, grams. | Containing Soluble Phos. Acid, grams. | Soil, grams. | Soil has per cent. Carbonate Lime. | Time of action, hours. | Grams of Soluble Phos. Acid Lost. | 100 parts of Soil Absorb. Sol. Phos. Acid. |
|---|---|---|---|---|---|---|---|
| 1. | 25 | 5 | 60 | 5.11 | 24 | 2.72* | 4.81* |
| 2. | 25 | 5 | 60 | 5.11 | 3 | 2.92 | 4.87 |
| 3. | 51 | 10 | 30 | 23.71 | 48 | 7.35 | 24.50 |
| 4. | 51 | 10 | 30 | 23.71 | 3 | 7.10 | 23.66 |
| 5. | 25 | 5 | 60 | 23.71 | 3 | 4.66 | 7.75 |

In order better to compare the above results, I have calculated the following (Table III):

**TABLE III.**

SHOWING FINAL ACTION IN TABLE II.

| Mixtures. See Table. | Soluble Phos. Acid lost in per cent. | Ratio between Soluble Phos. Acid and Soil. |
|---|---|---|
| 1. | 54.40* | 1 : 12 |
| 2. | 58.40 | 1 : 12 |
| 3. | 73.50 | 1 : 3 |
| 4. | 71.00 | 1 : 3 |
| 5. | 93.20 | 1 : 12 |

The observations that can be drawn from these experiments give nearly the same results noticed in the experiments of Voelcker, viz.:

1st. That presence of lime in the soil causes rapid precipitation of the soluble phosphoric acid of the superphosphates.

2d. The larger the content of lime the greater is the action.

3d. That the duration of action increases the amount precipitated, and

4th. The increase of the amount of the soil, where the superphosphate remains the same, naturally increases the precipitation, just as the increase of the content of lime in the soil would so increase it; for in each case the superphosphate is brought in contact with a larger amount of lime.

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*The results here recorded contain a mistake which was noticed in the original calculations; so in the comparison mixture 1 must be omitted.

To illustrate these results: A given quantity of soluble phosphoric acid is brought in contact with a moist soil containing 5.11 calcium carbonate; after three hours 58.40 per cent. of the phosphoric acid is precipitated. The same quantity of soluble phosphoric acid is next mixed with the same quantity as before of a moist soil containing $4\frac{1}{2}$ times as much calcium carbonate. The precipitation now amounts to 93.20 per cent. after three hours have elapsed, due, without much doubt, to the increased amount of lime in the mixture. Next the same quantity of soluble phosphoric acid is mixed with $\frac{1}{4}$ of the quantity of the soil of the last mixture, and after three hours 71.00 per cent. phosphoric acid is found to be precipitated; and by continuing the action after 48 hours 73.50 per cent. is precipitated, showing that the amount of the soil and the time of contact are also potent factors in the precipitation.

From these experiments we see that so far as lime soils are concerned the precipitation takes place, and takes place rapidly, when sufficient moisture is present to insure perfect contact. But how is it in regard to other soils—for many localities soils abounding in lime, such as the above experimental soils, are most rare? And indeed many of our soils are sadly deficient in this most useful of ingredients. Does iron and alumina act in the same manner, and does the presence of organic matter or other ingredients alter this action? And to what extent will this action continue after the lapse of time? These and other questions will be discussed in the following investigation.

It was endeavored as far as possible in the following experiments to imitate nature's action on the addition of superphosphates to the soil, and to retain the best conditions for obtaining strictly accurate analytical results. The disadvantage which one meets with at the first step in pursuing such investigation is the impossibility of having these natural conditions, even in cases where extreme care is taken; at best we can only approximate them. All of the conditions cannot be complied with: the effect of the frost, the rains and snow with the dissolved carbonic acid, the heat of the day and the cold of the nights; the variation

from the dry to the moist condition of the soil, all or nearly all have to be partially neglected and only in a crude way can they be imitated.

And again, the proportion of the soluble phosphoric acid of the superphosphate to the quantity of the soil in the experiment cannot be made to agree with that in nature; this also, in a general way, must be approximated.

The result, when reached, will express at least not absolute but relative results.

The plan pursued was to mix an acid phosphate with soils of different composition, and to observe by analysis the changes resulting from such a mixture after the lapse of time. The main difficulty experienced in the outset was that of procuring identical portions for analyses. One large heap mixed in the proper proportions and sampled at stated times would not answer the conditions; for the sampling itself might not contain the proper quantity of the soil and fertilizer, and so prove a fruitful source of error.

The difficulty was met by mixing at the same time many little heaps in the same proportion and in such quantity that the whole heap could be analyzed at stated intervals.

The details of the experiments were as follows:

A. The acid phosphate used was freshly prepared from S. C. Rock, carefully ground to pass a 60 mesh seive, and carefully mixed. Its analysis (using the method of Official Agricultural Chemist for 1886–'87, where the insoluble phosphate is treated for 30 minutes at a temperature of 65° C., shaking at intervals of 5 minutes) resulted as follows (Table IV):

**TABLE IV.**

ANALYSIS OF ACID PHOSPHATE.

| Moisture. | Total Phos. Acid. | | Sol. Phos. Acid. | | Insol. Phos. Acid. | |
|---|---|---|---|---|---|---|
| 10.05 | By fusion | 15.26 | Assoc. Method | 12.63 | Assoc. Method | 0.92 |
| | By Assoc. Method | 15.29 | Assoc. Method | 12.82 | Assoc. Method | 0.87 |
| | Average | 15.27 | Average | 12.72 | Average | 0.89 |

B. The soils chosen were four in number and of varied character. The original field sample was air dried, crushed with the

hand and put through a 60 mesh sieve. The fine earth (that passed the sieve) alone was used in the analysis and experiments. (See Table V).

The names of the varieties of soils below were given as suggested by Boussingault,* dependent on actual contents of the various ingredients, and were:

1. Sandy, with little Clay.
2. Stiff Clay.
4. Sandy, with Humus.
5. Clayey Sand.

**TABLE V.**

SHOWING ANALYSES OF SOILS.

| Variety of Soils. | Coarse Residue. | Fine Earth. | $H_2O$. | V. & O. Matter. | $SiO_2$ Insol. | $P_2O_5$. | $Fe_2O_3$, $Al_2O_3$. | CaO. | MgO. | $SO_3$. | $K_2O$. | $Na_2O$. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Sandy—Clay..... | 36.11 | 63.89 | 1.520 | 2.797 | 91.220 | 0.478 | 3.845 | .260 | .108 | .039 | .100 | .158 | 100.095 |
| 2. Stiff Clay..... | 20.75 | 79.25 | 5.975 | 4.752 | 58.955 | 0.204 | 28.125 | .830 | .625 | .062 | .050 | .004 | 99.882 |
| 3. Sandy—Humus | 4.73 | 95.27 | 15.160 | 18.840 | 63.370 | .048 | 1.795 | .470 | .077 | ..... | .070 | .101 | 99.931 |
| 4. Clayey Sand..... | 0.60 | 99.40 | 6.497 | 7.897 | 76.220 | .118 | 8.275 | .425 | .108 | ..... | .390 | .154 | 100.084 |

Each mixture consisted of 1 gram acid phosphate and 4 grams of the soil, and was carefully and thoroughly intermixed and stirred to a thick paste, by the addition of a few cubic centimetres of distilled water. A short glass rod was used for this purpose, which was allowed to remain in the mixture. The vessel containing the mixture was a small cylindrical glass jar, 50 mm. in diameter and 62 mm. high. Sixty-four of these mixtures, representing sixteen sets of each of the four varieties of soils, were prepared at the same time, each containing 1 gram of acid phosphate and 4 grams of soil. Each of the jars, covered with a small glass plate, was placed on one of a series of shelves in a covered wooden box about 12 inches square and 12 inches high.

A thermometer inserted in the box registered a mean temperature of 20° C.; the extreme variation during the whole time, 27 weeks, was 18°–24°, which was about the heat of the working laboratory.

*Rural Economy, Translated by Law, p. 226.

Four of these portions, representing each of the above soils, were analyzed immediately after mixing, four were analyzed two days after, four three days after, one week after, and so on. At the end of every week the contents of each of the vessels were stirred, and again moistened if at all dry.

In analyzing, the whole mixture, consisting of 5 grams, was treated with water and washed till no longer acid for the determination of phosphoric acid, then digested with 100cc. neutral ammonium citrate (S. G.=1.09) for 30 minutes at a temperature of 65° C.; and continuing according to the Association Method, referred to above, for the insoluble phosphoric acid, with some slight modification made necessary by the larger bulk of the materials. The total phosphoric acid of course remains the same throughout.

Allowing $\frac{1}{8}$ of the acid phosphate to be soluble phosphoric acid, we see that the ratio the soluble phosphoric acid bore to the soil was in the experiments, 1 to 32; *i. e.*, for every part of the soluble phosphoric acid in the mixture there existed 32 parts of the soil; a mixture more nearly representing nature than is recorded in the experiments of Wagner, where the ratio was 1 : 3 and 1 : 12.

In the table (Table VI) the corrected percentages of insoluble phosphoric acid are given, which were obtained by subtracting from the insoluble phosphoric acid found in the mixture the per cent. of phosphoric acid previously found in the different soils.

**TABLE VI.—SHOWING THE EFFECT OF SOILS ON ACID PHOSPHATES.**

| SOILS. | ACID PHOSPHATE. | Before Mixing. | AFTER MIXING THE SOILS WITH ACID PHOSPHATES. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | At Once. | 2 Days. | 3 Days. | 1 Week. | 2 Weeks. | 3 Weeks. | 4 Weeks. | 5 Weeks. | 6 Weeks. | 7 Weeks. | 8 Weeks. | 10 Weeks. | 14 Weeks. | 18 Weeks. | 27 Weeks. |
| 1. Sandy, with little Clay. | Sol. Phos. Acid | 12.72 | 12.31 | 11.21 | 10.85 | 9.44 | 9.42 | 7.85 | 6.50 | 7.68 | 7.50 | 7.43 | 7.36 | 7.10 | 6.37 | 6.13 | 5.17 |
| | Insol. Phos. Acid | 0.89 | .92 | 1.07 | 1.02 | .78 | .95 | .79 | .79 | .93 | .93 | 1.09 | 1.09 | 1.13 | .99 | .93 | 1.15 |
| | Reverted Phos. Acid | 1.66 | 2.04 | 2.99 | 3.40 | 5.05 | 4.90 | 6.63 | 7.98 | 6.66 | 6.84 | 6.75 | 6.91 | 7.00 | 7.91 | 8.21 | 8.95 |
| 2. Stiff Clay. | Sol. Phos. Acid | 12.72 | 11.16 | 7.91 | 7.02 | 6.17 | 5.76 | 4.12 | 4.17 | 3.90 | 3.79 | 3.58 | 3.17 | 2.84 | 2.12 | 1.82 | 1.55 |
| | Insol. Phos. Acid | 0.89 | .83 | 1.19 | 2.33 | 1.93 | 2.05 | 1.98 | 2.28 | 2.09 | 2.52 | 2.38 | 2.79 | 2.65 | 2.38 | 2.77 | 3.06 |
| | Reverted Phos. Acid | 1.66 | 3.28 | 6.17 | 5.32 | 7.17 | 7.46 | 9.17 | 8.82 | 9.28 | 9.06 | 9.31 | 9.40 | 9.78 | 10.77 | 10.68 | 10.66 |
| 3. Sandy, with Humus. | Sol. Phos. Acid | 12.72 | 13.23 | 13.53 | 12.97 | 12.72 | 12.15 | 11.21 | 10.75 | 11.44 | 10.75 | 11.23 | 11.10 | 10.69 | 9.80 | 9.01 | 8.67 |
| | Insol. Phos. Acid | 0.89 | .69 | .65 | .89 | .55 | .61 | .37 | .41 | .69 | .81 | .88 | .69 | .73 | .61 | .55 | .74 |
| | Reverted Phos. Acid | 1.66 | 1.35 | 1.09 | 1.44 | 2.00 | 2.51 | 3.69 | 4.11 | 3.14 | 3.71 | 3.36 | 3.48 | 3.85 | 4.86 | 5.71 | 5.86 |
| 4. Clayey Sand. | Sol. Phos. Acid | 12.72 | 12.09 | 10.26 | 10.00 | 9.03 | 8.57 | 7.85 | 7.14 | 6.38 | 6.49 | 6.77 | ..... | 5.83 | 5.18 | 4.75 | 3.83 |
| | Insol. Phos. Acid | 0.89 | .75 | .90 | .96 | .75 | .61 | .68 | .61 | .86 | .90 | .90 | .92 | 1.06 | .92 | .75 | .92 |
| | Reverted Phos. Acid | 1.66 | 2.52 | 4.11 | 4.31 | 5.49 | 6.09 | 6.74 | 7.52 | 8.03 | 7.88 | 7.60 | ..... | 8.38 | 9.17 | 9.77 | 10.52 |

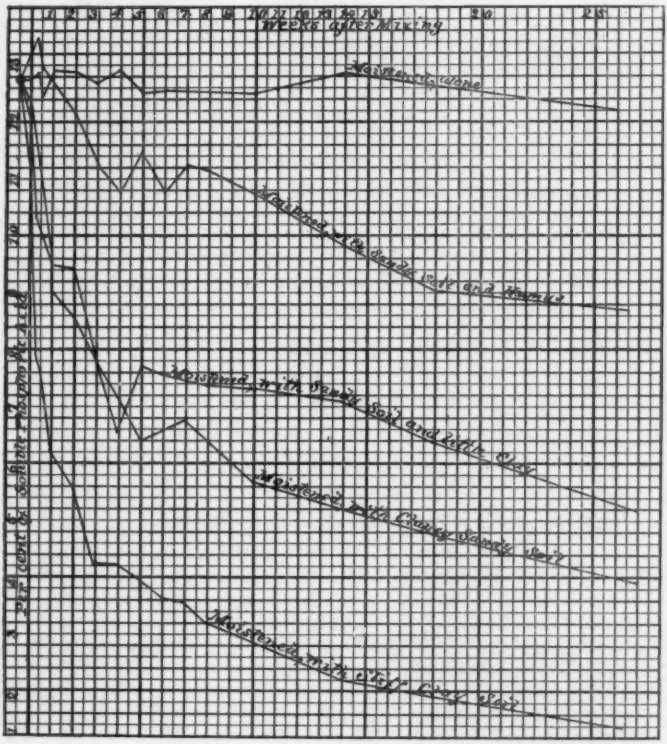
**TABLE VII.—SHOWING THE EFFECT OF MOISTENING ALONE ON ACID PHOSPHATE.**

PERIODS AS IN TABLE VI.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sol. Phos. Acid | 12.72 | ..... | 12.84 | 12.43 | 12.87 | 12.84 | 12.67 | 12.92 | 12.42 | 12.59 | ..... | ..... | 12.43 | 12.84 | ..... | 11.82 |
| | Insol. Phos. Acid | 0.89 | ..... | .69 | .69 | .77 | 1.05 | .90 | .90 | .96 | 1.04 | ..... | ..... | .84 | 1.13 | ..... | .77 |
| | Reverted Phos. Acid | 1.66 | ..... | 1.74 | 2.15 | 1.63 | 1.38 | 1.70 | 1.45 | 1.89 | 1.64 | ..... | ..... | 2.00 | 1.30 | ..... | 1.08 |

**CHART I.**

THE PRECIPITATION OF THE SOLUBLE PHOSPHORIC ACID OF A HIGH GRADE ACID PHOSPHATE (CONTAINING 12.72 PER CENT. SOLUBLE PHOSPHORIC ACID) DUE TO THE ACTION OF FOUR VARIETIES OF MOIST SOIL, FOR A PERIOD OF 27 WEEKS.


Weeks after Mixing
Moistened with Sandy Soil and Kills Clay
Moistened with County Sandy Soil
Moistened with Cliff Loam Soil

Thinking that the wetting itself might have some effect on the acid phosphate, a parallel line of experiments were carried on to ascertain if any change was due to this cause alone. The same quantity (1 grm.) of acid phosphate was used as in the above experiment with the result as indicated in Table VII.

We see from this table that the change due to the mere wetting of the acid phosphate may be said to be practically nothing, and, therefore, that the change in the content of the different forms of phosphoric acid when the superphosphate is applied to moist soils is due entirely to the action of the soil upon them.

In order better to compare the results I insert a graphic chart (Chart I) representing the variation of soluble phoshoric acid due to the action of moisture alone on the acid phosphate, and to the action of the four varieties of moist soil, for the whole period of 27 weeks. (See page 121).

The first noticeable effect is the immediate precipitation of a portion of the soluble phosphoric acid in all the soils, except the one containing a large quantity of organic matter, varying in amount in the various soils according to their composition, even to the extent of changing while in the course of analysis. That further on the precipitation proceeds gradually, increasing as time goes on. It will be noticed in soil 1 for the 4th week and soil 3 for the 5th week and 6th week a variation from this gradual increase occurs. I am inclined to think that some outside influence, such as the fumes of the laboratory or incomplete washing, may have caused this variation, though oscillation similar to this has been noticed in the reversion of superphosphates by Phillips,* and also Post,† quoted by Phillips. It is to be regretted that duplicate determinations could not have been made in order to settle this point.

It is plainly noticeable that the greatest precipitation occurs from contact with the soil containing the largest amount of iron and alumina, and the smallest precipitation with the soil with least iron and alumina. For example, in soil 3, where the con-

*Journal Mitchell Soc., I, p. 57.

†Chem. Indus., '82, p. 217.

tent of sesquioxides of iron and alumina (the iron here is really present as the protoxide) is only 1.795 per cent., the total precipitation during the whole period of 27 weeks is the slightest; that is, only 4.05 per cent. soluble phosphoric acid (in this case, however, other ingredients exert their influences, as will be discussed later), corresponding to 31.69 per cent. of the total soluble phosphoric acid present. In soil 1, containing the next highest content of iron and alumina (3.845 per cent.), the total precipitation is 7.55 per cent. soluble phosphoric acid, corresponding to 59.36 per cent. of the total soluble phosphoric acid. In soil 4, with the third higher content of iron and alumina (8.275 per cent.), the precipitation is 8.89 per cent., or 69.90 per cent. of the whole soluble phosphoric acid originally present. And lastly, in the soil containing the largest amount of iron and alumina (28.125 per cent.) the precipitation amounts to 11.17 per cent. for the whole period, corresponding to as much as 87.81 per cent. of the whole soluble phosphoric acid originally present. By referring to Table VIII this change can more readily be seen.

**TABLE VIII.**

SHOWING TOTAL PRECIPITATION OF SOLUBLE PHOSPHORIC ACID DURING 27 WEEKS WITH VARIOUS SOILS.

| SOILS. | Containing Iron and Alumina, per cents. | Total Precipitation of Sol. Phos. Acid, per cents. | Equivalent to Precipitation of whole Sol. Phos. Acid, per cents. |
|---|---|---|---|
| 3. Sandy, with Humus..... | 1.795 | 4.05 | 31.69 |
| 1. Sandy, with Little Clay..... | 3.845 | 7.55 | 59.36 |
| 4. Clayey Sand..... | 8.275 | 8.89 | 69.90 |
| 2. Stiff Clay..... | 28.125 | 11.17 | 87.81 |

As was referred to above in the case of soil 3, the precipitation is slight, due no doubt, 1st, to the small amount of iron and alumina present, but principally to the large content of organic matter present in the soil. The presence here of the organic matter, and the formation of organic acid, retards the decomposition of the soluble phosphate and consequently the change to the precipitated form.

Let us now look at the effect of the soils on the acid phosphate in regard to the insoluble phosphoric acid. With soils 1 and 4 there has been no change in the insoluble from the beginning to the end of the period; or if any exists it is slight and within the

limits of variation in analytical work. With soil 3, which contains the largest percentage of organic matter, we notice a decrease of insoluble phosphoric acid which, though slight, is decided. This important result is due undoubtedly to the presence of vegetable matter. It has been seen that organic matter prevents the decomposition of the soluble phosphoric acid. Now we see that another result is reached which is much more important; for the organic acids when formed actually act on the insoluble phosphoric acid present in the fertilizer, effect its decomposition, thus rendering it available to the plant, or it may be that by so preventing the precipitation of soluble phosphoric acid it furnishes the soluble with the means of acting on the undecomposed tricalcic phosphate to render it soluble in ammonium citrate. I am inclined to the former supposition; in either case the effect is the same.

On the other hand, in regard to soil 2 with the large percentage of iron and alumina the effect is just the reverse, for the presence of much ferric oxide and alumina renders some of the phosphoric acid originally available to the plants useless for such purposes, because some of the soluble phosphoric acid is changed to the insoluble. This reversion has indeed gone on till at the end of the 27th week it amounts to 2.15 per cent., or, in other words, 16.90 per cent. of the whole soluble phosphoric acid originally present has been converted into the insoluble form. This is due, I think, to the formation, with the large excess of ferric oxide and alumina in the soil, of basic phosphate of iron and alumina, which is, as stated by A. Millot,* not soluble in ammonium citrate at 65° C., as is the case with the normal phosphate.

The reverted phosphoric acid in the above series, embodying as it does the phosphoric acid soluble only in ammonium citrate, combines the change which has taken place in the soluble phosphoric acid by which a part is rendered insoluble in water, and also the change, if any, by which the phosphoric acid insoluble in ammonium citrate has become soluble in that liquid; consequently it is of much interest, and attention is called to it.

*Bull. de la Soc. Chim., 1880, p. 98.

In the foregoing experiments the quantity of soil is constant; *i. e.*, 32 times the content of soluble phosphoric acid in the superphosphate. It was thought desirable to ascertain if by increasing the quantity of soil the precipitation would be correspondingly increased, and to what extent this would take place.

Soil No. 2, with 28.125 per cent. ferric oxide and alumina, was taken for these experiments, because the change in soluble phosphoric acid would be more marked on account of the larger content of ferric oxide and alumina than in either of the other three.

The same acid phosphate was taken. The mixtures were made in the same way as previously but in different proportions, and analyzed after seven weeks.

*Mixture A.*—1 gram acid phosphate to 4 grams soil No. 2 (as in previous series), corresponding therefore to 1 part soluble phosphoric acid to 32 parts soil.

*Mixture B.*—¼ gram acid phosphate to 3 grams soil, corresponding thus to 1 part soluble phosphoric acid to 96 parts soil.

*Mixture C.*—¼ gram acid phosphate to 4 grams soil, corresponding therefore to 1 part soluble phosphoric acid to 128 parts soil.

*Mixture D.* —¼ gram acid phosphate to 6 grams soil, corresponding to 1 part soluble phosphoric acid to 192 parts soil.

The results obtained are recorded in Table IX, in which the percentages of insoluble phosphoric acid are corrected by subtracting the quantity of phosphoric acid present in the varying amounts of the soil.

**TABLE IX.**

SHOWING ACTION OF VARYING QUANTITIES OF SOIL No. 2 (WITH 28.125 PER CENT. OF $Fe_2O_3$ AND $Al_2O_3$) ON ACID PHOSPHATE (WITH 12.72 PER CENT. SOLUBLE PHOSPHORIC ACID AND 0.89 PER CENT. INSOLUBLE PHOSPHORIC ACID) AT THE END OF SEVEN WEEKS.

| Mixture. | Ratio Sol. Phos. Acid to Soil. | Actual per cent. Sol. Phos. Acid Found. | Total Precipitation. | Actual per cent. Insol. Phos. Acid Found. |
|---|---|---|---|---|
| A | 1 : 32 | 3.58 | 9.14 | 2.38 |
| B | 1 : 96 | 3.44 | 9.28 | ..... |
| C | 1 : 128 | ..... | ..... | 2.39 |
| D | 1 : 192 | 3.24 | 9.44 | 2.56 |

Here we see that the increase of the amount of soil increases the total precipitation, and increases also the amount of phosphoric acid rendered insoluble by the formation of basic phosphate of iron and alumina. The results are as would be expected in regard to the increase, but as to the amount of the increase the results are somewhat surprising.

For here, when the quantity of soil is three times what it was in the first experiment, the precipitation is only 0.14 per cent. greater in phosphoric acid; and with 6 times as much soil the total precipitation is only 0.30 per cent. And again, where the soil is four times greater, the insoluble phosphoric acid remains practically the same; and with six times as much soil gives an increase of only 0.18 per cent. phosphoric acid. Results like these, where would be expected a greater increase, seem to be anomalous.

Probably the only rational explanation which can be given is the following: When the superphosphate comes into intimate contact with the soil the particles of the former are surrounded by larger masses of the latter. Each separate particle of the phosphate, therefore, must be mingled with numerous particles of the soil, so that the soil particles touch it at all possible points. The number of the soil particles is of course limited by their fineness, and it can be easily seen that the number can be fixed; or, in other words, that a given particle of acid phosphate can only come in contact with a limited number of given soil particles. With this view, the anomaly can be explained by considering that the phosphate particle in the mixture is surrounded by a definite number of soil particles, and that this number is nearly reached when the mixture is 1: 32. A large increase of soil, therefore, has but little effect on the subsequent precipitation, for the additional soil particles cannot touch the already surrounded particle of the phosphate.

If this theory be correct, then, the series of experiments (Table IX) do not fall far short of what would actually be the case when the superphosphate is applied to the soil, if the latter remains in a continuous moist condition, and if the effect of heavy rains be disregarded.

We see from the above experiments that consequent upon the addition of acid phosphate to the soil a precipitation occurs by which some of the phosphoric acid soluble in water becomes no longer soluble in that liquid, but is readily dissolved by ammonium citrate at 65° C. This precipitation may continue until later a basic phosphate of iron or alumina, insoluble in ammonium citrate, forms.

The results brought out by these investigations are:

1st. The sesquioxides of iron and aluminium present in the soil, more than any other ordinary ingredients, precipitate to a marked degree the soluble phosphoric acid of the superphosphate applied to them.

2d. The precipitation varies in direct proportion to the content of ferric oxide and alumina.

3d. That this precipitation commences immediately when moisture is present, and continues to increase gradually till all the soluble is so precipitated.

4th. In soils containing much of the oxides of iron and aluminium basic phosphates of iron and alumina, insoluble in ammonium citrate at 65° C., commence to form at once, and increase very slowly.

5th. Organic matter by decomposition furnishes organic acids which prevent the precipitation of soluble phosphoric acid.

6th. The organic acids so formed either dissolve the tricalcic phosphates of the superphosphates, or by preventing the precipitation of soluble phosphoric acid allow it to act on the undecomposed phosphate, rendering it available to plants.

7th. The greater the proportion of soil to soluble phosphoric acid the greater the precipitation, but this is not proportional to the quantity of the soil.

8th. That a limit is soon reached beyond which an additional quantity of soil has very little or no effect on the superphosphate.

9th. This limit is caused by the impossibility of a larger number of soil particles coming in contact with the particles of superphosphate.

10th. The precipitate from the soluble phosphoric acid is readily dissolved by ammonium citrate at 65° C., until the basic phosphates are reached.

11th. That such precipitated forms (excluding the basic phosphates), judging by the ammonium citrate standard, are readily acted on by the juices of plants, and can be classed among the "available phosphates."

[NOTE.—The above article, with but few corrections, was written during the winter of '86–'87. Many additions and alterations which might safely be made have been prevented by press of other work.]

## A PARTIAL CHEMICAL EXAMINATION OF SOME SPECIES OF THE GENUS ILEX.

F. P. VENABLE.

Some years ago an analysis of the leaves of Ilex cassine was given in this Journal.* In this analysis appeared the interesting fact that these leaves contained a small percentage of caffeine. During the winter of 1885–'86, at the request of some medical friends whose attention was drawn to the analysis, a more thorough examination was undertaken, not only of the leaves but of the berries. It was thought advisable, at the same time, to examine the leaves and fruit of other representatives of the Ilex family in this State—*Ilex opaca* and *Ilex dahoon*. This was primarily a search after alkaloids and not intended as a complete chemical examination. As no alkaloids were found, other than the caffeine already mentioned, no account of the work was published, and the results have been hidden away in my note-books ever since. Thinking, however, that even negative results are often of some value and that the partial analysis might be of aid to others, I offer this paper for publication in the Journal of the Society.

*Vol. II, p. 39.

A short preliminary account of these members of the Genus Ilex, taken from the pages of Curtis,* will add to the value of the paper and make it more intelligible.

HOLLY. (*Ilex Opaca*, Ait.).—Thirty to forty feet high and twelve to fifteen inches in diameter. The wood is heavy, with a fine, compact grain, and takes a brilliant polish. The berries are purgative and fifteen or twenty of them will produce vomiting.

DAHOON HOLLY. (*I. Dahoon*, Walt.).—A shrub or small tree, from six to twenty-five feet high, growing on the borders of the pine-barren ponds and swamps of our low country. The leaves are one or two inches long, one-fourth to one-half inch wide, entire, or with a few sharp teeth near the upper end, evergreen. The berries are red.

YOPON. (*I. Cassine*, Linn.).—An elegant shrub, ten to fifteen feet high, but sometimes rising into a small tree of twenty or twenty-five feet. Its native place is near salt water, and it is never found far in the interior. The leaves are small, one-half to one inch long, very smooth, and evenly scolloped on the edges with small, rounded teeth. In some sections of the Lower District, especially in the region of the Dismal Swamp, these are annually dried and used for tea, which is, however, oppressively sudorific—at least to one not accustomed to it. The berries are a bright red.

According to Curtis there are in this State five additional species of this Genus—*I. decidua*, Walt.; *I. ambigua*, Chapm.; *I. verticillata*, Gray.; *I. glabra*, Gray.; *I. coriacea*, Chapm.—but the examination was not extended to them.

In searching for the alkaloids the directions of Dragendorff† were first followed. The leaves (or crushed berries) were digested at 40°—60° with dilute sulphuric acid. This extract was evaporated to a syrupy consistence, the residue mixed with three or four times its bulk of alcohol, filtered after twenty-four hours'

*The Woody Plants of North Carolina, 58 *et seq.*

†Blyth, Poisons; Effects and Detection, 224.

standing and washed with alcohol. The alcohol was then distilled off from the filtrate, the watery residue was diluted with water and filtered. Petroleum-ether, benzol and chloroform were successively used to extract the alkaloidal principles, if any were present in the acid liquid. Then, after rendering alkaline with ammonia, the liquid was again extracted with the solvents mentioned.

As, even with water but slightly acidified with sulphuric acid, some risk of the destruction or change of the alkaloids was run during the long evaporation, a second method was made use of as follows:

The leaves were digested for ten hours with 70 per cent. alcohol, the alcohol distilled off and the residue treated with lead acetate and soda. The excess of lead was removed by means of sulphuretted hydrogen and the filtrate from this evaporated to a thin syrup. This was then treated with strong alcohol, filtered, and the excess of alcohol distilled off. Bismuth-potassium iodide and sulphuric acid was next used to precipitate any alkaloid present. The presence of albuminoid matter rendered it necessary to decompose this by means of soda, neutralize with dilute sulphuric acid, and re-precipitate with mercuric chloride. The solutions to which mercuric chloride had been added were allowed to stand several days. The results may be tabulated as follows:

| | |
|---|---|
| I. opaca, leaves | No alkaloid. |
| I. opaca, berries | " " |
| I. dahoon, leaves | " " |
| I. dahoon, berries | " " |
| I. cassine, leaves | Caffeine. |
| I. cassine, berries | No alkaloid. |

I regard these analyses as conclusive, at least, of the absence of the known, well characterized alkaloids. It is, of course, possible that other methods might reveal the presence of some of the more elusive ones.

# REPORT OF THE RECORDING SECRETARY.

J. W. GORE.

### THIRTY-SEVENTH MEETING.

PERSON HALL, September 11, 1888.

The Society was called to order by the Vice-President, Professor Graves, who presented a paper on—

1. The Principle of Duality. (Abstract). The author's remarks were confined to the application of the principle to plane figures. We may consider in a plane figure either the point or the right line as the element. The co-existence of figures and their properties (correlative), as the different elements are chosen, constitutes the Principle of Duality. Several illustrations were given (c. f. Cremona's Projective Geometry). The subject also may be considered from an analytical stand-point (c. f. Clebsch's Lessons in Geometry). Tangential co-ordinates were explained and compared with the more familiar point co-ordinates. A series of parallel, and analytically identical, operations may be executed on certain equations which lead to results which have a similar algebraic form but bear different and correlative interpretations.

2. An Account of the Meeting for 1888 of the American Association for the Advancement of Science was then given by Professor Gore. Points of interest with regard to this meeting, and statistics as to papers read, with titles and outlines of same, were given.

3. Report on Progress in Chemistry. (Abstract). Dr. Venable described some of the recent discoveries in Chemistry and the progress made in that branch of science.

The Vice-President announced the committees which were to report, at the meetings during the year, on the progress in the different branches of scientific work. There were nine of these committees and the reports were limited to fifteen minutes each.

The Secretary reported large additions to the library during vacation. Since the May meeting 484 books and pamphlets had been received. The list of exchanges had increased to 184. The names of the following new members were read:

Dr. S. J. Hinsdale, Fayetteville, N. C.

Dr. P. B. Barringer, Davidson College, N. C.

THIRTY-EIGHTH MEETING.

GERRARD HALL, October 16, 1888.

Vice-President Graves introduced Dr. Wm. B. Phillips, who gave an account of the—

4. Erection of the Mitchell Monument. An abstract of this paper is published in this Journal (p. 55).

THIRTY-NINTH MEETING.

PERSON HALL, November 20, 1888.

Vice-President Graves presided. The meeting was opened by Professor Alexander with a paper on—

5. References to Oil in Plutarch and Some of his Theories Concerning the Moon. (Abstract). Passages from Plutarch's writings were cited to show the use of oil in quieting the sea, also by divers for illuminating the depths, etc. The petroleum spring near the oxus, discovered about 328 B. C., was referred to and Strabo's mention of similar oil-springs given. Some of the quaint theories as to the nature of oil were recounted. Professor Alexander also gave Plutarch's theories about the moon, the faces appearing on its disc, etc.

6. The University Observatory. By Professor Love. The following hitherto unpublished facts about the North Carolina University Astronomical Observatory have been lately gathered from old MS. records:

The foundations were laid in April, 1831, and the first eight feet of the wall built. This portion was of stone. The remainder of the walls was put up in March, April and May, 1832. The wood-work, painting and all were complete by the middle of August, 1832. The building cost $430.29. It was paid for by the University and not, as has been stated, by President Caldwell.

7. Report on Progress in Bacteriology. Presented by Professor Poteat; read, in the absence of the author, by the Secretary. (Abstract).

The Report on "Microscopical Botany," after a brief historical introduction, called attention to the opening of laboratories for the study of micro-organisms, particularly to the Hoagland Laboratory of the Long Island College Hospital, opened October 1st. The remaining portion was occupied with the description of Hesse's and of Frankland's methods for the quantitative estimation of the bacteria disseminated in the air, and of Koch's "plate-cultivation" process as applied to the dissemination of bacteria in water. Some of the general results of these investigations were stated.

8. Mathematical Fiction. Read by Professor Graves. (Abstract). In Natural Science fiction finds a place at the foundation of important theories. In Mathematics, also, which claims to be *the* exact science, fictions are found which, to the uninitiated, appear extravagant.

Illustrations: The properties of the right line at infinity, of the circular points at infinity, of the imaginary foci of conics, etc., etc.

9. Recalculations of Atomic Weights. This paper by Dr. Venable appears, in full, in this Journal (p. 98).

The Secretary reported 286 books and pamphlets received since the September meeting and fourteen new exchanges.

The following new members were reported:

Professor W. H. Michael, Wake Forest, N. C.

Professor A. L. Purinton, Wake Forest, N. C.

Professor H. L. Smith, Davidson, N. C.

Seventeen additional Associate Members were received as follows:

W. J. Andrews,
Gaston Battle,
Wm. J. Battle,
J. D. Bellamy,
J. C. Braswell,
J. S. Lewis,
J. V. Lewis,
W. H. Rankin,
P. L. Woodard,
F. L. Covington,
B. T. Green,
H. L. Harris,
W. E. Headen,
T. M. Lee,
W. H. Shaffner,
W. L. Spoon,
G. S. Wills.

FORTIETH MEETING.

Person Hall, December 4, 1888.

Vice-President Graves presided. Professor Gore read a paper on—

10. Magnetic Variation for the State of North Carolina.

As this report was only a partial one its publication is postponed until it can be completed.

11. Progress in Analytical Chemistry. Report made by Dr. Venable. (Abstract). This report bore special reference to commercial methods of analysis. Some of the difficulties in the way of the Technical Analyst and the approximative nature of the methods pursued were pointed out. The necessity for uniformity and recent efforts in that direction by associations of chemists and interested bodies were mentioned.

12. "On the Chords of a Parabola and generally of a Conic." By Professor Graves. (Abstract). This is the title of a paper by Professor F. Amodeo, of Naples, Italy, published in Vol. IV, p. 92, of the Annals of Mathematics. As the title indicates, it extends the properties proved by Graves for the "Focal Chord of a Parabola" (Vid. Annals of Mathematics, Vol. III, p. 153; also Journal Mitchell Soc., Vol. V, p. 15).

13. Chemical Examination of some Species of the Genus Ilex. Professor Venable read this paper by title. (This paper is published in full in this Journal.)

14. On the Change in Superphosphates when they are applied to the Soil. By Dr. H. B. Battle. (Read by title). (Published in full in this Journal).

The Secretary reported nine additional exchanges since the November meeting and 174 books and pamphlets received.

Photographs of the Mitchell Monument and interesting views in the vicinity of Mt. Mitchell were shown.

# A LIST OF SOCIETIES, ETC.,

## EXCHANGING PUBLICATIONS WITH THE SOCIETY.

### UNITED STATES.

#### SCIENTIFIC SOCIETIES.

ALBANY—New York Museum of Natural History.
BOSTON—American Academy of Arts and Sciences.
Boston Scientific Society.
BROOKVILLE—Society of Natural History.
CAMBRIDGE—Entomological Club.
CHARLESTON—Elliott Society of Science and Arts.
CINCINNATI—Society of Natural History.
DAVENPORT—Academy of Natural Sciences.
DENVER—Colorado Scientific Society.
GRANVILLE—Denison Scientific Association.
MADISON—Wisconsin Academy of Arts and Sciences and Letters.
MANHATTAN—Kansas Academy of Natural Sciences.
NEW BRIGHTON—Natural Science Association of Staten Island.
NEW HAVEN—Connecticut Academy of Arts and Sciences.
NEW ORLEANS—Academy of Sciences.
NEWPORT—Natural History Society.
NEW YORK—Academy of Sciences.
American Museum of Natural History.
Linnean Society.
Microscopical Society.
Torrey Botanical Club.
PEORIA—Science Association.
PHILADELPHIA—Academy of Natural Sciences.
American Philosophical Society.
Franklin Institute.
Wagner Free Institute of Science.
PROVIDENCE—Franklin Geological Society.
SACO—York Institute.
SALEM—Essex Institute.
Peabody Academy of Science.
SAN FRANCISCO—California Academy of Science.
ST. LOUIS—Academy of Science.
TRENTON—Natural History Society.
URBANA—Central Ohio Scientific Association.
WASHINGTON—Chemical Society.
National Academy of Sciences.
Philosophical Society.

AGRICULTURAL STATIONS AND SOCIETIES.

AGRICULTURAL COLLEGE—Michigan Agricultural Experiment Station.
AGRICULTURAL COLLEGE—Mississippi Agricultural Experiment Station.
AMES—Iowa Agricultural Experiment Station.
AMHERST—Massachusetts Agricultural Experiment Station.
ATHENS—Georgia Agricultural Experiment Station.
AUBURN—Alabama Agricultural Experiment Station.
BATON ROUGE—Louisiana Agricultural Experiment Station.
BERKELEY—California Agricultural Experiment Station.
BLACKSBURG—Virginia Agricultural Experiment Station.
BOSTON—Massachusetts Horticultural Society.
BROOKINGS—Dakota Agricultural Experiment Station.
BURLINGTON—Vermont Agricultural Experiment Station.
CHAMPAIGN—Illinois Agricultural Experiment Station.
Illinois State Laboratories of Natural History.
COLLEGE STATION—Texas Agricultural Experiment Station.
COLUMBIA—Missouri Agricultural Experiment Station.
COLUMBIA—South Carolina Agricultural Experiment Station.
COLUMBUS—Ohio Agricultural Experiment Station.
CORVALLIS—Oregon Agricultural Experiment Station.
FAYETTEVILLE—Arkansas Agricultural Experiment Station.
FORT COLLINS—Colorado Agricultural Experiment Station.
GENEVA—New York Agricultural Experiment Station.
GRAND RAPIDS—Michigan Horticultural Society.
HANOVER—New Hampshire Agricultural Experiment Station.
ITHACA—Cornell University Agricultural Experiment Station.
KNOXVILLE—Tennessee Agricultural Experiment Station.
LEXINGTON—Kentucky Agricultural Experiment Station.
LINCOLN—Nebraska Agricultural Experiment Station.
MANHATTAN—Kansas Agricultural Experiment Station.
MINNEAPOLIS—Minnesota Agricultural Experiment Station.
NEWARK—Delaware Agricultural Experiment Station.
NEW BRUNSWICK—New Jersey Agricultural Experiment Station.
NEW HAVEN—Connecticut Agricultural Experiment Station.
ORONO—Maine Agricultural Experiment Station.
RALEIGH—North Carolina Agricultural Experiment Station.
North Carolina Horticultural Society.
STATE COLLEGE—Pennsylvania Agricultural Experiment Station.
ST. ANTHONY PARK—Minnesota Agricultural Experiment Station.

GEOLOGICAL SURVEYS.

ALBANY—New York State Geological Survey.
CHEYENNE—Wyoming Territorial Geological Survey.
COLUMBUS—Ohio State Geological Survey.

INDIANAPOLIS—Indiana State Geological Survey.
LITTLE ROCK—Arkansas State Geological Survey.
MINNEAPOLIS—Minnesota State Geological Survey.
NEW BRUNSWICK—New Jersey State Geological Survey.
RALEIGH—North Carolina State Geological Survey.
SAN FRANCISCO—State Mining Bureau.
SPRINGFIELD—Illinois State Geological Survey.
TUSCALOOSA—Alabama State Geological Survey.

BOARDS OF HEALTH AND MEDICAL SOCIETIES.

ALBANY—New York State Board of Health.
APPLETON—Wisconsin State Board of Health.
BOSTON—Massachusetts State Board of Health.
COLUMBIA—South Carolina State Board of Health.
LANSING—Michigan State Board of Health.
NASHVILLE—Tennessee State Board of Health.
PHILADELPHIA—Pennsylvania State Board of Health.
TRENTON—New Jersey State Board of Health.
WILMINGTON—North Carolina State Board of Health.
North Carolina Medical Journal.
North Carolina Medical Society.

EDUCATIONAL INSTITUTIONS.

COLUMBIA SCHOOL OF MINES—Chemical Society.
CORNELL UNIVERSITY—Scientific Bulletins.
DENISON UNIVERSITY—Bulletins from the Scientific Laboratories.
HARVARD UNIVERSITY—Museum of Comparative Zoology.
JOHNS HOPKINS UNIVERSITY—Circulars.
Studies from the Biological Laboratory.
WASHBURN COLLEGE—Laboratory of Natural History.

OBSERVATORIES.

BLUE HILL—Meteorological Observatory.
CAMBRIDGE—Harvard University Observatory.
ROCHESTER—Warner Observatory.
UNIVERSITY OF VIRGINIA—Leander McCormick Observatory.

INDEPENDENT PERIODICALS.

BALTIMORE—Modern Language Notes.
CRAWFORDSVILLE—Botanical Gazette.
BOSTON—Popular Science News (presented).
SAN DIEGO—West American Scientist.

GOVERNMENT DEPARTMENTS.

AGRICULTURAL DEPARTMENT—Division of Botany.

AGRICULTURAL DEPARTMENT—Division of Chemistry.
Division of Entomology.
Division of Forestry.
Division of Pomology.
Division of Statistics.
BUREAU OF ETHNOLOGY.
COAST AND GEODETIC SURVEY.
DEPARTMENT OF STATE.
FISH COMMISSION.
GEOLOGICAL SURVEY.
NATIONAL BOARD OF HEALTH.
NATIONAL MUSEUM.
NAVAL OBSERVATORY.
SIGNAL SERVICE BUREAU.
SMITHSONIAN INSTITUTION.
SURGEON GENERAL'S OFFICE.

AUSTRIA.

INNSBRUCK—Der Naturwissenschaftlich-medizinische Verein.
WIEN—Der Wissenschaftliche Club.

BELGIUM.

BRUXELLES—La Société Royale Malacologique de Belgique.
BRUXELLES—La Académie Royale de Medecine de Belgique.

BRAZIL.

RIO DE JANEIRO—Museu Nacional.

CANADA.

GRIMSBY—Fruit-Growers' Association of Ontario.
HALIFAX—Nova Scotian Institute of Natural Sciences.
MONTREAL—Natural History Society.
OTTAWA—Entomological Society of Ontario.
Field Naturalists' Club.
Geological Survey of Canada.
Royal Society of Canada.
TORONTO—Canadian Institute.
WINNIPEG—Historical and Scientific Society.

CHILI.

SANTIAGO—Der Deutsche Wissenschaftliche Verein.

FRANCE.

AMIENS—La Société Linneenne de Normandie.

CAEN—La Société Linneenne du Nord de la France.
PARIS—Bulletin Scientifique de la France et de la Belgique.
Le Laboratoire Municipal de Chemie.
ROUEN—La Société des Amis des Sciences Naturelles.

GERMANY.

AUGSBURG—Der Naturhistorische Verein.
BERLIN—Botanischer Verein für die Provinz Brandenburg.
Entomologischer Verein.
Gesellschaft Naturforschender Freunde.
Naturae Novitates.
BONN—Naturhistorischer Verein.
BRAUNSCHWEIG—Verein für Naturwissenschaft.
BRESLAU—Die Schlesische Gesellschaft für vaterl. Cultur.
CARLSRUHE—Naturwissenschaftlicher Verein.
DANZIG—Naturforschende Gesellschaft.
FRANKFURT AM MAIN—Senckenbergische Naturforschende Gesellschaft.
FRANKFURT AM ODER—Der Naturwissenschaftliche Verein.
Societatum Litterae.
GIESSEN—Oberhessische Gesellschaft für Natur u. Heilkunde.
HALLE—K. Leopoldinisch-carolinische Deutsche Akad. d. Naturforscher.
HANAU—Wetterauische Gesellschaft für die gesammte Naturkunde.
HANNOVER—Naturhistorische Gesellschaft.
HEIDELBERG—Naturhistorisch-medizinischer Verein.
KIEL—Naturwissenschaftlicher Verein für Schleswig-Holstein.
LEIPZIG—Insekten-Börse.
LUNEBURG—Naturwissenschaftlicher Verein.
MAGDEBURG—Naturwissenschaftlicher Verein.
MUNSTER—Der Westfälische Provinzial-Verein f. Wissenschaft u. Kunst.
OFFENBACH—Verein für Naturkunde.
REGENSBURG—Naturwissenschaftlicher Verein.
WIESBADEN—Nassauischer Verein für Naturkunde.

GREAT BRITAIN AND IRELAND.

BELFAST—Naturalists' Field Club.
BRISTOL—Naturalists' Society.
DUBLIN—Royal Dublin Society.
DUMFRIES—Natural History and Antiquarian Society.
GLASGOW—Geological Society.
Natural History Society.
HALIFAX—Yorkshire Geological and Polytechnic Society.
LONDON—Royal Society of England.
MANCHESTER—Geological Society.
Literary and Philosophical Society.
ROTHAMSTED—Agricultural Experiment Farm.

ITALY.

CATANIA (Sicily)—Academia Gioenia di Scienze Naturali.
PISA—Societa Toscana di Scienze Naturali.
TORINO—Musee di Zoologia ed Anatomia comparata della R. Universita di Torino.

MEXICO.

MEXICO—Sociedad Mexicana de Historia Natural.

NETHERLANDS.

AMSTERDAM—K. Nederlandische Akademie d. Wissenschaften.
HARLEM—Musee Teyler.
MIDDELBURG—Zeeuwsch Genootschap der Wetenschappen.
UTRECHT—La Société Provinciale des Arts et des Sciences.

RUSSIA.

KHARKOW—La Société des Sciences Experimentales (Section Medicale).
KIEFF—La Société des Naturalistes.
MOSCOW—La Société Imperiale des Naturalistes.
ODESSA—La Société des Naturalistes de la Nouvelle-Russie.

SWEDEN.

LUND—Universitets Bibliotek.

SWITZERLAND.

BERN—Naturforschende Gesellschaft.
FRAUENFELD—Thurganische Naturforschende Gesellschaft.
FRIBOURG—La Société Fribourgeoise des Sciences Naturalles.
LAUSANNE—La Société Vaudoise des Sciences Naturalles.
ZURICH—Die Naturforschende Gesellschaft.